7 CONCEPTUALIZATION OF IN-SERVICE BIOLOGY TEACHERS' PEDAGOGICAL CONTENT KNOWLEDGE (PCK) DURING A LONG-TERM PROFESSIONAL DEVELOPMENT PROGRAM

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Abstract

A case study of four in-service biology teachers revealed the possible relationship between pedagogical content knowledge (PCK) and the professional development process during a long-term course. Here we suggest a potential assertion of PCK components which enabled us to characterize a significant one: teaching strategies. Teachers in this study paid major attention to their unique teaching strategies in both their practice and their initiative development. The teaching strategies conception was found to be consistent and resistant to change. The teachers expanded their conception of teaching strategies over the course of the professional development program and developed their initiatives accordingly. We recommend that professional development designers be aware of this PCK component and find means of expanding it for better performance.

Keywords: pedagogical content knowledge (PCK); professional development; teaching strategy; conception; initiative

1. Introduction

A new program aimed at expanding science teachers' knowledge and empower them to improve science education in Israel was established at the Science Teaching Department of the Weizmann Institute of Science during the 2008-09 academic year. The new long-term program provides resources and professional support for knowledge expansion in both science and science education. Its main outcomes are designing and implementing initiatives to improve the teaching of science in high schools in Israel. The rationale for the biological part of this program lies in designing initiatives that are based on teaching needs as stated by the biology teachers themselves. This program addresses biology teachers' will, experience and knowledge, based on the well-known fact that teachers are an important resource for the implementation of changes in schools (Magnusson, Krajcik, & Borko, 1999; Parke & Coble, 1997; Tytler, Symington, & Smith, 2011; Van Driel, Beijaard, & Verloop, 2001).

Experienced teachers bring with them a unique teaching knowledge, termed pedagogical content knowledge (PCK) (Ball, Thames, & Phelps, 2008; De Jong & Van Der Valk, 2007; Lee & Luft, 2008; Loughran, Milroy, Berry, Gunstone, & Mulhall, 2001; Loughran, Mulhall, & Berry, 2008; Magnusson et al., 1999; Shulman, 1986). Many researchers have indicated that teachers' PCK guides their actions in teaching specific content in class (Lee &

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Luft, 2008; Magnusson et al., 1999; Van Driel et al., 2001; Van Driel, De Jong, & Verloop, 2002). However, little is known about the connection between biology teachers' PCK and the process of professional development in the course of developing initiatives in biology education—the focus of this study. As such, the study is based on the theoretical frameworks of PCK and professional development, which are briefly discussed in the following.

1.1 Teachers' knowledge base: PCK

Teachers and researchers agree that special knowledge is acquired by teachers during their teaching career. It was Shulman (1986) who first suggested referring to this knowledge as a special knowledge domain, the PCK. Researchers agree upon the nature of PCK as an integration of knowledge, skills and beliefs, acquired through teaching, and used in the context of teaching a specific content (Ball et al., 2008; De Jong & Van Der Valk, 2007; Lee & Luft, 2008; Loughran et al., 2001, 2008; Magnusson et al., 1999).

In an effort to analyze the PCK concept, researchers have variously categorized it, resulting in eight major categories of conceptualization (Lee & Luft, 2008; Park & Oliver, 2008; Van Driel, Verloop, & De Vos, 1998): 1. *knowledge of subject matter*; 2. *knowledge of representations and instructional strategies*; 3. *knowledge of student learning and conceptions*; 4. *knowledge of general pedagogy*; 5. *knowledge of curriculum and media*; 6. *knowledge of context*; 7. *knowledge of purpose* (some researchers refer to this component as *orientation toward science teaching and learning*); 8. *knowledge of assessment*.

PCK relates to teachers' knowledge, i.e. their professional knowledge base. This knowledge base refers to two different kinds of information: *knowledge* and *beliefs*. Knowledge refers to information that is certain, solid, dependable, and supported by research. Beliefs are what we think we know or may be coming to know based on new information; they are supported by experience, and people are strongly committed to them (Loucks-Horsley, Love, Stiles, Mundry, & Hewson, 2003).

Beliefs about the teaching practice are described in the literature in various ways (Van Driel, Bulte, & Verloop, 2007). In the literature on teachers' PCK, the term *orientation* toward teaching science is related to teachers' ideas about which subject matter is important to teach, and thus influences the choices teachers make in their teaching (Cohen & Yarden, 2009; Gess-Newsome, 1999; Magnusson et al., 1999; Van Driel et al., 2007). Teaching beliefs, from a constructivist perspective, are regarded as *conceptions* about the nature of science, scientific concepts, and how to learn and teach them (Da-Silva, Ruiz, & Porlan, 2006). Experienced science teachers have teaching conceptions that have been consolidated by their own professional experience, and these are usually stable and resistant to change. Sometimes this is because they feel satisfied with their teaching conception, and there is coherence between their goals, their conceptions, their educational practice and their perception of their students (Da-Silva et al., 2006); other times this may be because the conception is associated with a positive mood or because it was critical to the individual's survival (Sinatra & Mason, 2008).

Teachers' knowledge and beliefs inform the choices they make in terms of professional development (Loucks-Horsley et al., 2003), and may inform the designers of professional development programs on factors that they have to take into account while designing the programs.

1.2 Professional development

Teachers are able to take what they have learned from a professional development course and incorporate it into an ongoing program in the subject covered by the course. This places teachers' professional learning at the very center of what can be gained from such programs (Tytler et al., 2011). On the other hand, most subject-matter courses in teacher education programs are viewed by teachers as having little bearing on the day-to-day realities of teaching and little effect on the improvement of teaching and learning (Ball et al., 2008). There are no guidelines for which designs are right in a particular situation.

It is assumed that teachers need knowledge and skills to enhance the effectiveness of professional development programs and their ability to adapt to possible changes in their teaching. The concept of change itself denotes a "disruption in the status quo". Individuals possess a natural tendency to remain in a steady state, so any changes that disrupt this are viewed with caution and are only accepted if the perceived outcomes add value to the individuals (Hanley, Maringe, & Ratcliffe, 2008). It has been suggested that effective professional development programs should engage the teachers' knowledge and experience in decision-making for new curriculum and instructional issues as they reflect the connection between theory and practice (Parke & Coble, 1997). The professional development program examined in this study shifts the focus from teacher-training workshops, aimed at implementing curricula developed by others and sometimes removed from the teachers' experience, knowledge and beliefs, to promotion of the teachers' professionalism as curriculum developers. Promoting teachers' professionalism with acquisition of academic knowledge and participation in collaborative workshops may empower them to become more thoughtful about their profession (Parke & Coble, 1997). However, the process is rather complex, one reason being the importance of teachers' PCK base and its relation to the professional development program. Thus, the process of teachers' empowerment within a long-term professional development program is not straightforward.

The professional development program examined in this study was designed to help in-service teachers expand their knowledge in biology and biology education through designing initiatives that could be incorporated in the biology classroom. The ability to design and implement various types of science teaching initiatives that will be aligned with teachers' different PCK and students’ different cognitive abilities and learning styles is seen as an important component in professional development (Hofstein, Carmi, & Ben-Zvi, 2003). Thus, this study's major objective was to characterize the possible changes in in-service biology teachers' PCK during the course of a long-term professional development program.

The specific research questions were:

1. What are the PCK components of the four biology teachers who participated in the program?
2. How do the various PCK components of these four teachers develop during the course of the program?
3. What are the relative proportions of PCK components related to teaching aspects in each of the four teachers?
4. How do the teaching strategy conceptions of each participating teacher develop over the course of the program?

2. Research design and methods

2.1 Research context

This research focused on four in-service biology teachers participating in a special professional development program established at the Weizmann Institute of Science. The main rationale of this program is to use the participating teachers' teaching knowledge, both scientific and educational, and experience to mutually design advances in the high-school biology program in Israel. The program's curriculum ran for eight hours weekly over the course of two academic years (Table 1). Each semester, the teachers participated in a different subject matter-oriented course in biology followed by a curriculum development course aimed at developing initiatives that might enhance biology teaching and learning in Israel. The course was named: "Initiatives development in biology". At the end of the day, the teachers participated in a basic science education course. The first author of this study was one of the instructors of the initiatives development course.

Table 1. Daily outline of the professional development program. Each period lasted approximately 45 minutes with two 15- to 30-minute breaks during the day.

Periods	Course type
1-2	Biology course
3-6	Initiatives development course
7-8	Science education course

2.2 Sample

Of 27 biology teachers who submitted applications, five were selected to join the program, based on academic achievements, excellence in the teaching realm and motivation to develop initiatives. One of the five teachers missed numerous lessons in the first year and chose not to participate in the second year. Thus, this study focused on four teachers who fully participated in the professional development program. All teachers had M.Sc. degrees in biology and their teaching experience ranged from 6 to 17 years at the beginning of the program.

2.3 Research design

This study addressed the process of the teachers' professional development and the possible relations with specific PCK components during the course of initiatives development. Data were collected from multiple sources:

1. recorded lessons from the initiatives development course
2. recorded conversations about designing the initiatives and the participating teachers' reflections
3. e-mail correspondence between the teachers and researchers
4. the participating teachers' written assignments which were handed in to the initiatives course instructors

5. recorded presentations of the initiatives to other teachers
6. interviews with the program participants at the end of each year.

The data from the various sources were analyzed chronologically, according to the four phases of the course.

Phase 1: Eliciting prior knowledge and background. Conversations about teachers' dreams, teaching goals and the first meeting with the chief supervisor of biology education in Israel, assignments and e-mail correspondence about the teachers' professional background, expectations from the program and general ideas about initiatives in biology (Aug-Nov 2008).

Phase 2: Planning the initiatives. Lessons, conversations, assignments, e-mail correspondence, and initial presentations of ideas for initiatives and of preliminary parts of the initiatives to the group members, researchers in science education and the chief supervisor of biological education in Israel (Dec 2008-Feb 2009).

Phase 3: Assessing the initiatives. Lessons on initiatives assessment, reflective conversations about poster presentation of the initiatives, e-mail correspondence, questionnaires and interviews about the teachers' experiences after teaching and assessing a preliminary part of their initiative in class (Mar-Jul 2009).

Phase 4: *Writing and distributing the initiatives* to other teachers, researchers and science education students. Lessons on writing a teacher's guide, presentations of the initiatives, conversations, assignments, e-mail correspondence, and interviews with the participating teachers at the end of the program (Oct 2009-May 2010).

2.4 Data analysis

The groups' discussions, interviews, relevant e-mails, assignments, activities and lessons were fully transcribed. The data were divided into different episodes, which were classified according to their theme. We initially analyzed the PCK components according to the taxonomy suggested by Lee and Luft (2008), who summarized the main PCK categories appearing in the current literature, but we had difficulty aligning our data with a few of their categories. We therefore performed a qualitative analysis according to Shkedi (2003) and Chi (1997) and allowed categories of teachers' PCK to emerge from the data. The following steps were taken:

1. We read the transcripts several times and searched for recurrent categories and ideas as recommended by Shkedi (2003). Then the following four steps were taken: (i) forming primary categories from the collected data; segmenting the data into units, and categorizing every unit according to its content; (ii) developing more general domains; (iii) mapping all data according to the chosen domains; (iv) reorganizing the data according to the chosen domains. We then proposed assertions about the teachers' PCK components, and their possible relations with the teachers' professional development while designing the initiatives.

2. We attempted to capture the representations of the teachers' PCK as they were expressed in the data and to determine how those representations change with knowledge acquisition and actions, following Chi (1997). The verbal analysis added a quantitative dimension to our qualitative analysis.

Our assumption that the above methods would be successful in capturing the teachers' PCK components, although the data were not based on observations of the teachers' practice, is based on Van Der Valk and Broekman's (1999) "lesson preparation method" study. Those

authors reported that this method is successful in the sense that teachers produce "rich" information about their PCK while reporting on their lesson design and teaching.

To validate the results, data were analyzed by the first author at two time points, six months apart. In addition, data were presented to five researchers in science education for peer validation twice during the data analysis. The first peer validation was used to examine the identity rate between the suggested PCK domains and their related components. The mean identity rate between the five researchers and the suggested classification of the three PCK domains and their related components was 92.3%. The identity rate of the "teachers' world" alone was 97.1%, the identity rate of the "students' world" alone was 83.3% and the identity rate of the "initiatives' world" alone was 96.6%.

The second peer validation examined the suggested analysis of the possible changes in the teachers' PCK along the program. Twenty-five episodes were given to three science education researchers who were asked to classify each episode according to the suggested PCK classification. The overall validation rate was 85.6%. Moreover, interviews were used for interpretive validity with the participants following the analysis of the teachers' PCK change. The relevant results on PCK dynamics were presented to each teacher, who were asked to express their opinions on the accuracy of the results. The validation rate was 94%.

3. Results

3.1 PCK components of the four teachers from the program

The teachers' PCK components were analyzed from the bottom up according to Shkedi (2003). Nineteen PCK components emerged in the course of this analysis, and were grouped into three main domains: teachers' world, students' world and initiatives' world (Figure 1). The components are numbered chronologically and described in detail below:

1. *Knowledge and beliefs about the teachers' world*, namely, about teaching science. This includes knowledge and beliefs about: i) difficulties in biology teaching; ii) the personnel that accompany the teaching (e.g. school principal or chief supervisor of biological education); iii) assessment of related contents; iv) teaching strategies; v) subject matter; vi) curriculum; vii) available teaching facilities.

2. *Knowledge and beliefs about the students' world*, namely, about students' learning processes. This includes knowledge and beliefs about: viii) students' prior knowledge; ix) students’ thinking skills; x) students' motivation to learn science; xi) means to promote students’ meaningful learning; xii) students' interest outside of the school context; xiii) the influence of science learning on students' future life.

3. *Knowledge and beliefs about the initiatives' world*, namely, about the process of development, assessment and distribution of initiatives. This includes knowledge and beliefs about: xiv) writing useful teachers' guide materials; xv) the process of initiative development; xvi) personal feelings during the development process; xvii) modes of assessing initiatives; xviii) means of distributing initiatives; xix) possible collaborations during initiative development.

Most of the above PCK components have strong correlations with the categories suggested in the literature. The initiatives' world contains components that are very specific to initiative development and thus may not be adequately correlated to the literature categories.

Figure 1. The three main domains of PCK emerging from this research.

3.2 Changes in the teachers' PCK components during the course of the program

To reveal possible changes in the four teachers' PCK during the course of the program, we examined the research data according to the four phases of the course. Initially, we asked the teachers, in various ways, to describe their work, in order to capture the teachers' PCK prior to their learning in the initiatives program. In the three subsequent phases, we looked for possible changes in the teachers' PCK during the program and during the development of their initiatives.

Verbal analysis of the data following Chi (1997) revealed the proportion of each PCK component among the participating teachers and its change (Figure 2). Close examination of the data revealed some mutual patterns of the teachers' PCK components along the four phases of the course.

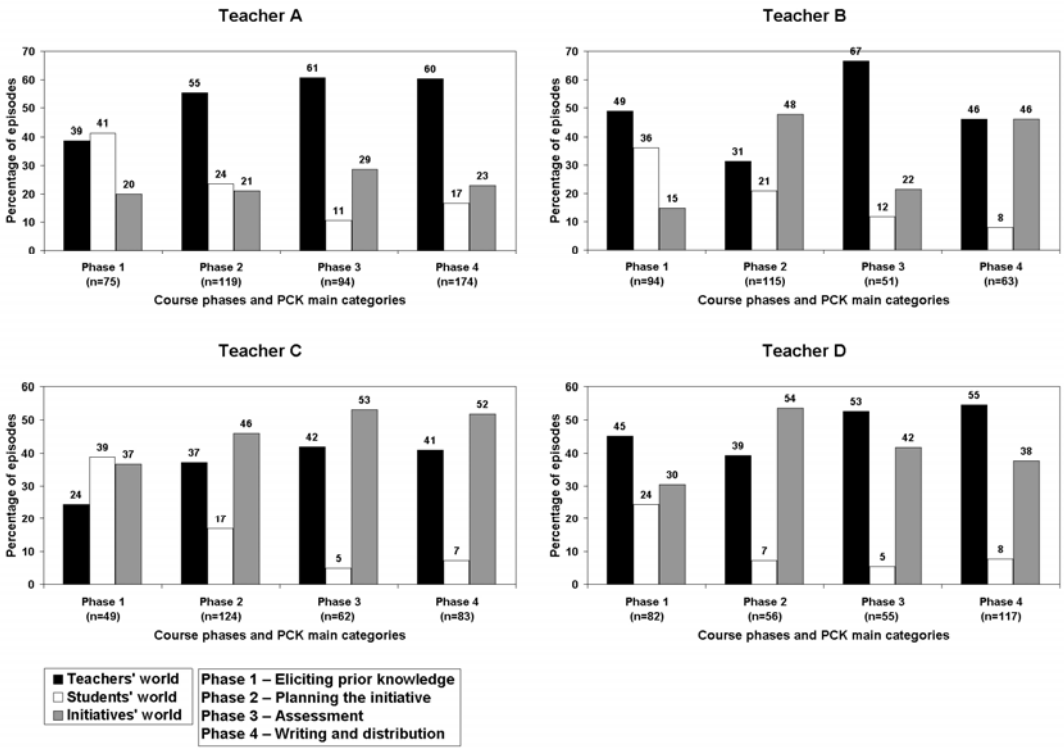

Figure 2. Distribution of the PCK domains for the four participating teachers through the four phases of the two-year program. Above each column, the percentage of each PCK domain is shown.

The relative proportion of the initiatives' world remained steady or grew during the course of the program (Figure 2). The increase was expected, due to the course's contents and goals. These teachers were offered to design initiatives for the first time in their career, and thus

they concentrated on themes related to initiative design, implementation and distribution. In contrast, the relative proportion of the students' world component decreased dramatically during the course of the program, particularly during phases 2 and 3. Since the teachers related less to the students' world in the materials collected during the course of the study, the meaning of the students' world component for the teachers' PCK cannot be revealed, due to the absence of discourse about this world.

The most interesting finding was an increase in the relative proportion of teachers' world as the course progressed and the fact that it stayed relatively high during phases 2-4. Thus, the teachers' world held significant weight in the teachers' PCK during the initiatives program. These results led us to carefully examine the components of the teachers' world to understand which PCK component is more important to the teachers during the course.

3.3 The relative proportion of teachers' world components in the teachers' PCK

In this section, we focus on the findings regarding the teachers' world. Presented in Figure 3 are the relative proportions of components of the teachers' world from episodes during the four phases of the course.

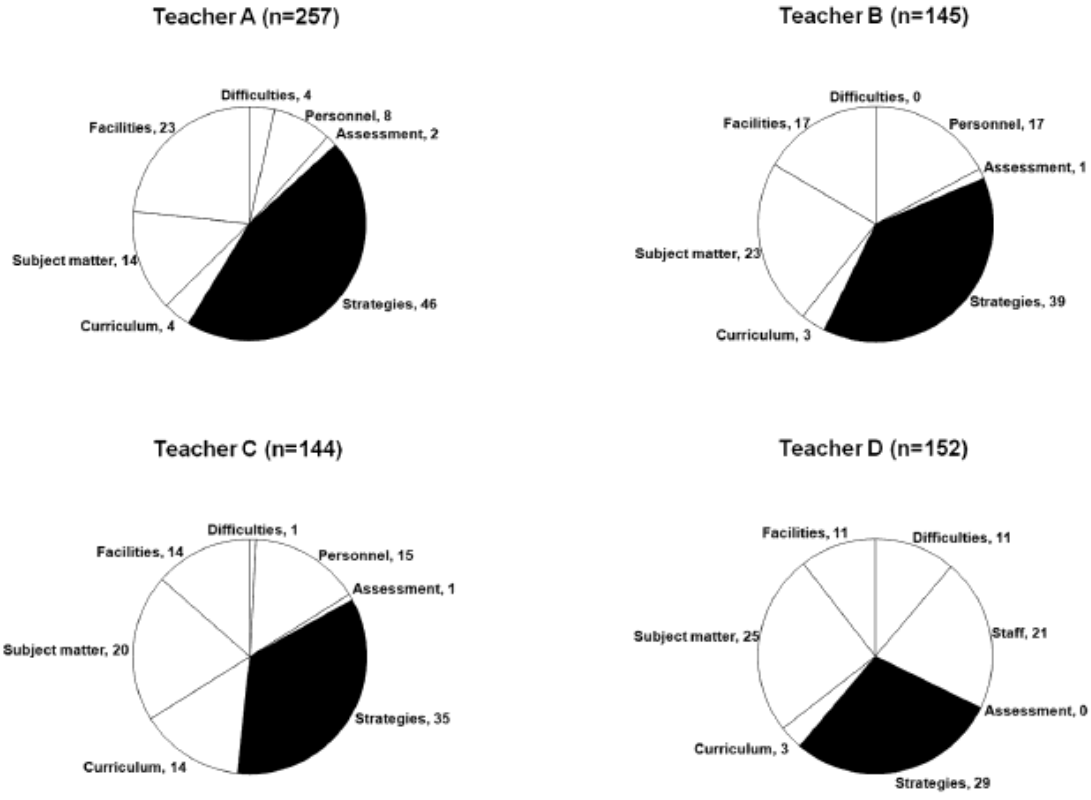

Figure 3. Percentage of teachers' world PCK components during the initiatives course.

The most frequent teachers' world component for all four teachers was teaching strategies. All four teachers dedicated a third or more of their attention to this component. Although other patterns differed within the teachers' world data, the consistent dominance of the

teaching strategies led us to focus on this component to reveal its significance to the teachers' professional development process.

3.4 Changes in the teaching strategies component for each teacher during the program

Teachers A, B and C each consistently related to a different, unique teaching strategy, which could be defined as the teachers' conceptions about teaching strategies due to their consistency and uniqueness. These teaching strategy conceptions expanded during the initiatives course, as described in detail below. Each teacher is described as a case study.

Teacher A increased her attention to the teachers' world during phases 2-4 of the study (Figure 2). In addition, Teacher A dedicated 45% of her attention to the teaching strategies component (Figure 3). At the beginning of the program, Teacher A concentrated on connecting the contents of several concepts and processes in biology as a leading teaching strategy concept aimed at helping students learn meaningfully. In phase 2, she developed an initiative that uses laboratory-based skills to strengthen biological knowledge that had been previously learned in class. In that way, Teacher A expanded her teaching strategy conception to a strategy that connects skills and content. Teacher A ended the program developing a different initiative that enables the student to use high-order thinking skills, such as inquiry-based laboratory skills, to learn new contents. Thus, Teacher A further expanded her teaching strategy conception to one that works to connect high-order thinking skills and knowledge construction, in order to scaffold meaningful learning.

Teacher B dedicated 39% of her attention during the program to the teaching strategies component (Figure 3). Her attention to the teachers' world showed a particular increase in phase 3 (Figure 2). Teacher B developed bioethical dilemmas together with Teacher C. Teacher B had a very strong conception about teaching using interesting stories from everyday life. In the first phase, she described her teaching strategy as random, connected to everyday life stories in order to motivate her students to learn. In her initiative design in phase 2, she concentrated on a story about a family with a genetic disease. She saw this story as the main scaffold of an initiative that might scaffold the students' knowledge. As the course continued, she began to understand the importance of teaching according to the teaching sequence of the syllabus and of planning the lesson in advance. This occurred in phase 3, when she assessed and reflected on her initiative after teaching it in her class, and she thus expanded her teaching strategy conception to be more ordinate and syllabus-related. Along with the improvement in her teaching strategy, Teacher B improved the contents of the initiative by bringing other stories that better explained the dilemmas in question. By the end of the program, she was still looking for "interesting stories" to teach and insert into her initiative design, and a relatively high percentage of her attention was still on the teachers' world (Figure 2).

Teacher C was Teacher B's partner in developing bioethical dilemmas. Teacher C's attention to the teachers' world increased during phases 2-4 (Figure 2); 35% of Teacher C's attention was given to the teaching strategies component. Teacher C had a very strong conception about teaching biology as a means of educating her students on human values. Her main focus was on collecting arguments for and against the dilemmas from various aspects: religious, economic, legal, moral and political. In the initial phase, she paid relatively little attention to the importance of scaffolding biological knowledge in her practice; she gave relatively less attention to the teachers' world (Figure 2). At the end of phase 3 and during phase 4, Teacher C began to seriously refer to the scaffolding of biological content knowledge in her initiative as well as in her practice. In phase 3, she reported that she had become more aware of meaningful learning and spent time establishing students'

understanding while teaching: in addition to humanity education, she began asking questions, and thus establishing students' knowledge, evidencing an expansion of her teaching strategy conception.

Teacher D's data show that although about a third of her attention was focused on the teaching strategies component (Figure 3) and she increased her attention to the teachers' world in phase 3-4, unlike the other three teachers, she did not hold a central conception about teaching strategies. Most of the data show that during the meetings, Teacher D mainly asked the others about their teaching strategies. During phase 1, she did not speak about her teaching strategies at all, but instead spoke relatively more about her difficulties in teaching biology. Teacher D was the least experienced of the four, and it appears that she had not yet developed her unique teaching strategy conception. Along with difficulties in her practice, she experienced difficulties in developing her initiative, which consisted of adapted primary literature articles in ecology. As the program continued, Teacher D felt that she had had a good experience in teaching her initiative. She reported in phase 3 that her students had shown interest in the content of the article, even during a school trip to the desert. After asking many questions about the right way to teach articles in class, Teacher D decided to teach them using a strategy of students' knowledge construction via teacher's questions. Along with the progression in the initiatives development (phases 3 and 4), Teacher D stopped complaining about teaching difficulties and kept referring to the teachers' world (Figure 2) in trying to construct her teaching strategy conception.

These data show that the three experienced teachers of this program (A-C) had developed their unique teaching strategy conceptions during their long years of practice. The only teacher who did not have a clear teaching strategy conception tried to establish it during the professional development program. Nevertheless, all four teachers showed progress in their practice throughout the course of the program.

4. Discussion

For many teachers, professional development programs are an opportunity for professional renewal (Tytler et al., 2011), where they become students and thus engage their own existing knowledge in the acquisition of new knowledge. In our program, the teachers not only learned new scientific and science education knowledge, they also developed new initiatives on the basis of their knowledge, professional experience and needs. As such, the course requirements combined knowledge with practice, and it was therefore expected that the teachers would use their PCK as a basis for further professional development. Science teachers are regarded as having conceptions about the nature of science, about scientific concepts and about how to learn and teach them (Da-Silva et al., 2006). This study proposes that conception about teaching strategies is a significant component of in-service teachers' PCK.

The experienced teachers that took part in this research had unique conceptions of teaching strategies that were resistant to change. The high proportion of the teaching strategies component in the research data implies that this is a significant factor in the teachers' practice and professional development. Although conceptions are resistant to change, they are capable of expansion. The less experienced teacher in this study had not yet established her unique teaching strategy conception. However, she attempted to form one throughout our program.

Designers of professional development programs should be aware of the unique teaching strategy conceptions that each teacher may hold. They can then focus on expanding them for

better performance or try to help a teacher who does not hold any such conceptions to establish one.

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