Chapter 4

Experienced science teachers’ learning in the context of educational innovation

Abstract: As to provoke teachers’ learning in the context of educational innovation, it is important to investigate how in-service teachers keep up their knowledge or adapt to changing professional circumstances. We investigated the learning of a small group of science teachers in the context of the implementation of a new science syllabus in upper secondary education in the Netherlands. The Story-line method (Gergen & Gergen, 1986) was used to elicit the teachers’ perceptions of their learning from experiences at work in their first few years of teaching the new syllabus. We focused on three aspects of learning, namely, teachers’ learning activities, courses of development, and changed competences as experienced by the teachers themselves. From the results two qualitatively different ways of learning were identified. Type I represents a revolutionary development in a teacher’s engagement in mainly individual activities in the working context, and Type II represents an evolutionary development in a teacher’s participation in individual and collaborative activities in the working context. Implications for professional development initiatives in the context of educational innovation are discussed.
4.1 Introduction

Science education in the Netherlands has traditionally been discipline-oriented and compartmentalized. The subject contents (physics, chemistry, and biology) could well be described as diluted forms of academic contents with little practical relevance and few possibilities for students to relate school knowledge to real-life experiences (De Vos & Reiding, 1999). The will to educate students in dealing with everyday situations that involve science and technology is at the basis of many new curricula in science education. Current educational innovations, in the Netherlands and abroad, show an orientation of science towards relevant life-world contexts (Westbroek, 2005). Subject matter is introduced and practiced in the framework of real-life issues. In many cases, these issues are taken from what students know from their own everyday lives, but social or professional science and technology contexts are also used this way. The ‘context approach’ is inspired, among other things, by the need to raise students’ attention and motivation for science (Bennet & Holman, 2002).

The introduction of a new syllabus on Public Understanding of Science (PUSc.) in the Netherlands is an example of the above-mentioned innovations in science education. The new syllabus has a strong Science-Technology-Society (STS) flavour (cf. Solomon & Aikenhead, 1994; Yager, 1996). In this regard, it bears similarities to science programmes in other countries, such as Canada (LORST, Aikenhead, 1991) and the UK (SATIS, Hunt, 1990). The introduction of PUSc. coincides with a general move towards (social) constructivist teaching strategies in Dutch secondary education. Science teachers in the Netherlands, therefore, are not only challenged with a new syllabus and real-life contexts, but they are also invited to implement activities in science classrooms which support students’ active construction of knowledge and understanding.

4.1.1 Aim of the study

In order to improve the implementation of important innovations, it is necessary to gain an insight into the ways teachers’ learning can be stimulated (Verloop, 1999). To this end, analytical research is needed on teachers’ learning processes in their natural settings. In research on teachers on the job, the question to be answered is how in-service teachers keep up their knowledge or adapt to changing professional circumstances (cf. Boulton-Lewis, Wills, & Mutch, 1996).

Theories and models of teacher learning already exist, but many of these prescribe how teachers should learn, neglecting how the process actually takes place. Furthermore, most of the educational literature available on this topic deals with student teacher learning (e.g., Oosterheert, 2001; Oosterheert & Vermunt, 2003). The field encompassing the learning of experienced teachers is a relatively under-researched area. The studies in which in-service teacher learning was investigated mostly focused on professional development initiatives for collegial learning, such as classroom visitation and peer coaching (e.g., Showers & Joyce, 1996; Bergen, 2002; Engelen, 2002). Research on learning from experiences at work (thus integrated in the teachers’ work itself) is of recent date (e.g., Eraut, 2000; Kwakman, 1999, 2003;
Lohman & Woolf, 2001; Van Eckelen, 2005). Up to now, few empirical investigations have been conducted into teacher learning in the workplace in the context of a specific educational innovation.

The innovation that is central in the present study, Public Understanding of Science (PUSc.), was introduced in 1999 and is taught by teachers who are experienced in teaching physics, chemistry, or biology. Dutch senior secondary education includes two streams: HAVO, general senior secondary education (Grades 10 and 11), and VWO, pre-university education (Grades 10, 11, and 12). In addition, students can choose between the streams of ‘science and technology’ and ‘humankind and society’.

The latter choice means that students drop the science subjects of physics, chemistry, and biology after Grade 9. The PUSc. syllabus taught in Grades 10, 11, and 12, however, is compulsory for all students in upper secondary education, whatever their backgrounds or educational levels. In order to teach PUSc., teachers of physics, chemistry, and biology must have mastery of concrete, context-based subject matter contents and of teaching methods which are based on a social constructivist view on knowing and learning. In addition, they should be able to deal with differences between pre-university (VWO) students and general (HAVO) students, and between science and non-science students.

We examined the learning in the workplace of a small number of teachers of physics, chemistry, and biology in their first few years of teaching the new syllabus. To this end we formulated the following general research question:

*In what ways did experienced teachers of physics, chemistry, and biology learn in the workplace, in the context of the implementation of a new syllabus on Public Understanding of Science?*

We aimed in this study to contribute to the development of knowledge about teachers’ learning in the workplace in the context of educational innovation, and with that, about teachers’ learning in the workplace in general. We also aimed to generate ideas that can be used in supporting and coaching teachers’ execution of future innovations in science education.

### 4.2 Workplace learning

From a situative view on cognition, learning and knowing is assumed to be integrally and inherently situated in the everyday world of human activity (Brown, Collins, & Duguid, 1989; Greeno, Collins, & Resnick, 1996). As teachers’ learning is embedded in everyday activities (Darling-Hammond, 1998; McLaughlin, 1997; Putnam & Borko, 2000), teacher learning in the workplace takes place as a result of teachers’ participation in activities in the working context. This context can be seen as broader than classrooms and schools, also including various communities such as cross-school professional groups of people or networks. This learning is considered to be not only individual, but also social in nature (cf. Jarvis, 1987; Solomon & Perkins, 1998). As teachers’ learning in the context of innovation is strongly connected with professional goals, this learning is referred to as ‘professional learning’. In order to specify teachers’ professional learning in the workplace in the context of innovation, we focused on teachers’ engagement in those individual and collaborative activities (i.e., ‘professional
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learning activities”) in the working context that helped them in their professional development (cf. Kwakman, 2003).

To explore factors affecting Dutch teachers’ participation in professional learning activities, Kwakman (2003), using interviews, identified a range of activities of secondary teachers from which learning could evolve. Most of these activities could be categorized (p. 155) within the pre-defined learning categories of reading, experimenting, reflecting, and collaborating, which Kwakman had drawn from the professional development literature.

In a study on how teachers learn (and their willingness to do so), Van Eekelen (2005) investigated work-related learning events of Dutch secondary teachers, using interviews and an electronic diary. Applying a phenomenographic method to analyse the data, she defined four categories of learning strategies in relation to the activities of the teachers (p. 27), that is, learning by doing (the teacher learned by doing a task on his own), learning in interaction (the teacher learned in interaction with students, colleagues, or external experts), learning by reading (the teacher learned by self-study), and learning by thinking (the teacher took time to reflect and think about school matters).

In an interview study on self-initiated learning activities of experienced American public school teachers (and the organizational characteristics that influenced their participation in those activities), Lohman and Woolf (2001) found that experienced teachers engaged in three main types of self-initiated learning activities (p. 65). In knowledge exchanging, teachers shared and reflected on others’ practices and experiences by talking, collaborating, observing, and sharing resources. Through experimentation, they tried out new instructional tools and techniques. Through environmental scanning, teachers individually scanned and gathered information from sources outside the school.

The empirically defined categories, or types, of learning events (Van Eekelen, 2005) or self-initiated learning activities (Lohman and Woolf, 2001) in the workplace did not appear to differ greatly from the categories of professional learning activities (Kwakman, 2003) derived from professional development theories.

We explored science teachers’ professional learning activities in the workplace, in the context of the implementation of a new syllabus on Public Understanding of Science. To find out, empirically, how the teachers’ learning occurred, we examined the combinations of ‘professional learning activities’ the teachers engaged in, the changes in frequencies and combinations of these activities over a number of years, and the ways their professional competences changed over time.

To answer the general question (In what ways did experienced teachers in physics, chemistry, and biology learn in the workplace, in the context of the implementation of a new syllabus on Public Understanding of Science?), we formulated three specific research questions to be answered first:
1) From what combinations of professional learning activities did teachers of Public Understanding of Science learn in the workplace in their first five or six years of teaching PUSc? 

2) How can the course of teachers’ competence development be typified, that is, how did the combination of activities, and the frequency with which these activities occurred, change over this period of time? 

3) How can the changes in teachers’ competences be described, that is, how did competences with respect to subject matter contents and teaching methods change over this period of time? 

4.3 Methodology and research design

We start this section with a description of the participants in the study and how they were selected. Next, some attention is paid to the Story-line method (Gergen & Gergen, 1986). We then turn to the description of the research instrument and the research procedure followed.

4.3.1 Participants in the study

The study was conducted among eight PUSc. teachers working at five different schools. They all used the same teaching method (‘ANiWoord’), in which the educational aims of the new syllabus are well represented. The eight teachers responded to a written invitation we sent to the users of the ANiWoord method. After meetings we organized at their schools (to explain the purposes and conditions), the teachers agreed to take part in the study. The teachers, all male, varied with regard to their backgrounds, years of teaching experience, and original disciplines (Table 4.1). They were all among the first PUSc. teachers at their schools.

Table 4.1 Features of the participants

<table>
<thead>
<tr>
<th>School</th>
<th>Number of teachers in the study</th>
<th>Disciplinary backgrounds</th>
<th>Years of teaching experience* in 2004</th>
<th>Years of teaching experience** in 2004</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>2</td>
<td>1 biology</td>
<td>18</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 chemistry</td>
<td>11</td>
<td>5</td>
</tr>
<tr>
<td>B</td>
<td>1</td>
<td>1 biology</td>
<td>28</td>
<td>6</td>
</tr>
<tr>
<td>C</td>
<td>1</td>
<td>1 physics</td>
<td>14</td>
<td>5</td>
</tr>
<tr>
<td>D</td>
<td>3</td>
<td>1 biology</td>
<td>14</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 chemistry</td>
<td>12</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 physics</td>
<td>29</td>
<td>6</td>
</tr>
<tr>
<td>E</td>
<td>1</td>
<td>1 physics</td>
<td>26</td>
<td>5</td>
</tr>
</tbody>
</table>

* in the teachers’ own discipline
** in PUSc.

Before they started to teach PUSc., the teachers took part in an in-service training course (‘Introductory course’) to become qualified to teach the new science subject. This course consisted of workshops and conferences (60 hours in total) and self-regulated study activities (also adding up to 60 hours). A basic assumption was that the
only possible outcome of such a short course could be the gaining of a starter’s competence. To address the fact that the Introductory course was only the beginning of a learning process for teachers, ‘cooperative learning’ and the production of a ‘portfolio’ were introduced as central characteristics of this course (Kapteijn, 1997). Exemplary instruction materials were used in the course programme; portfolio tasks obliged the teachers to try these materials out in their classrooms. The teachers, taking the role of students, practiced alternative teaching methods, such as debating and discussing ethical issues.

Teachers at school B and school D started to teach the new syllabus in 1998. The other teachers (like teachers at most secondary schools in the Netherlands) started the implementation of PUSc. in 1999. At the time of this study (2004), the teachers had either six or five years of experience in teaching the PUSc. syllabus (Table 4.1).

4.3.2 The Story-line method
Given the difficulty of eliciting answers to questions about workplace-related learning (cf. Van Eekelen, 2005), we needed a strong ‘trigger’ to make teachers talk about the development of their competences with regard to teaching PUSc. Inspired by Beijaard, Van Driel, and Verloop (1999), the Story-line method was used to address this problem. In this method, teachers evaluated and classified their own competences, and presented this by drawing a story-line. Beijaard et al. (1999) successfully applied the Story-line method in various studies on experienced teachers’ relevant experiences and events in their careers, related to a particular aspect of teaching (e.g., their interaction with students). Gergen and Gergen (1986) used the method in research on college-students’ feelings of general well-being, and recently, Van der Sanden and Teurlings (2003) reported the use of the Story-line method, in combination with individual interviews, to investigate work-related learning processes of students enrolled in higher social work education.

A story (cf. a ‘narrative’, Connelly & Clandinin, 1990) refers to an account of experiences or events shared through written or oral language. Those who tell them always weigh stories evaluatively (Gergen & Gergen, 1986). In this respect, a story-line represents a person’s evaluations of a series of experiences or events (e.g., with regard to teaching PUSc.) on the vertical axis of a graph, usually on a five- or seven-point scale, and plotted in time on the horizontal axis.

The rudimentary forms of a story-line are progressive, stable, and regressive lines, with which -in combination- many variations can be constructed (cf. Beijaard et al., 1999). For example, it is possible that a certain teacher had insufficient competences (in his opinion) when he started teaching PUSc., that these competences were sufficient after a few years, and now are weighed up by the teacher as remaining sufficient. Based on an evaluation of his competences throughout the years, this teacher will draw a story-line that can be qualified as progressive in the beginning, followed by a stable period.

We expected that not just the directions and inclines of the story-lines, but also, and in particular, the teachers’ spoken stories or narratives would contain the information we needed to answer our research questions: while drawing the lines, the teachers were
asked to give their comments on them, aloud. The teachers’ comments would contain information about activities they engaged in that, in their perception, had been helpful in the development of their competences (i.e., ‘professional learning activities’, research question 1). The teachers’ spoken stories would also provide information about the course of their development (research question 2), and the changes in their competences (research question 3) in the period under investigation. In the next section, the research instrument developed and the procedure of data collection followed is explained in further detail.

4.3.3 Research instrument and data collection

To investigate the ways experienced teachers of physics, chemistry, and biology learned in the workplace in the context of the implementation of PUSc, the Story-line method was applied to eight teachers from five different schools (three teachers whose original teaching disciplines were physics and biology, and two teachers of chemistry; see Table 4.1), in September 2004. We made the teachers’ learning operational by investigating their perceptions of their development of competences in teaching the PUSc syllabus between its introduction at the school in 1998, or 1999, and the conducting of the Story-line method in September 2004.

Because of the new context-based subject matter of the new syllabus, we first asked the teachers to evaluate their competences with regard to relevant science contents. We aimed to make a distinction between competences in the subject matter content of PUSc. in general, and competences in a specific domain of the syllabus, that is, in the topic of the ‘Solar system and Universe’ (throughout this paper referred to as ‘the Universe’). With this, we aimed to investigate whether or not the teachers’ learning with respect to subject matter content differed for the subject of ‘the Universe’ (which is one of the more unfamiliar topics in the entire syllabus) and for PUSc. as a whole.

Because the implementation of PUSc. coincided with the introduction of alternative teaching strategies, we next asked the teachers to evaluate their competences in relevant teaching methods. Again, we distinguished between methods that they perceived to be relevant to PUSc. in general, and methods that were seen as relevant to the specific subject of ‘the Universe’. According to the teacher instructions (see Appendix I), the teachers were asked, after a short introduction by the first author, to plot the perceptions of their competences on a scale from 1 to 5 (1 = insufficient, 3 = sufficient, 5 = very good, on the vertical axis of a graph), first in September 2004 and then in September 1998 or 1999. We used four different graphs for this purpose. In each case, we asked the teachers to explain their scaling for both 2004 and 1998 (or 1999).

While drawing the lines symbolizing the course of development in their competences between these two moments in time, the teachers were encouraged to comment aloud on their own drawings. To help the teachers think and talk about their own development, additional questions were asked (such as, ‘Why does the line stabilize at that time?’ or ‘Did something happen in that particular period?’). Finally, the teachers were asked to think about their future development (i.e., to tell their stories in
4.4 Analysis

In this section, we discuss how the research data were analysed in order to describe 1) the teachers’ professional learning activities (research question 1); 2) the teachers’ course of development (research question 2); and 3) the teachers’ changed competences in subject matter contents and in teaching methods with regard to PUSc. and to the subject of ‘the Universe’ (research question 3).

Codes for professional learning activities were developed and tested on the data. The final codebook was the result of different steps of testing and adapting the codes, until the first and second authors reached consensus on all codes to be used.

4.4.1 Research question 1: Professional learning activities

The data analysis started with the reading of the teachers’ transcribed stories (which they had told while drawing their four story-lines). Next, we selected all the teachers’ comments about the development of their competences that contained professional learning activities (as interpreted by the authors). These activities had to be coded. Codes for professional learning activities were developed for this purpose, based on the four categories of experimenting, reading, reflecting, and collaborating (Kwakman, 2003, p.
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155). The developed codes were tested on the data, to see if all the variations in the teachers’ comments could be covered. As this was not the case, some codes representing learning activities not subsumed under the categories taken from Kwakman were added to our list. These codes represented activities categorized as ‘Interacting with students’ and ‘Doing’ (cf. Van Eekelen, 2005), and ‘Experiencing’. We changed the category of ‘Reading’ to ‘Information gathering’ (cf. Lohman & Woolf, 2001), as the latter category could also contain (in addition to the reading of study books, papers, and journals) other activities by which teachers had gathered information, such as browsing the Internet and attending conferences. We removed codes about ‘Coaching’ activities (subsumed by Kwakman under the category of ‘Reflecting’), because these activities were absent in the teachers’ comments. The final codebook consisted of seven categories, including a total of 27 professional learning activities (Appendix II). All learning activities are named, categorized, and illustrated with examples in Table 4.2.

The seven categories of professional learning activities used to code the teachers’ statements were 1) Learning by doing, referring to growth through the practice of teaching; 2) Learning by experiencing, referring to the construction of knowledge on the basis of acting in real-life situations or in computer simulations; 3) Learning by experimenting, referring to a way of learning through intentional and conscious undertaking of activities, in an effort to do something new in the classroom; 4) Learning by information gathering, referring to reading, using multimedia, and attending professional conferences; 5) Learning by reflecting individually, referring to thinking deeply about one’s own way of teaching, for example, reflecting upon a completed lesson; 6) Learning by interacting with students, referring to learning from classroom communication with students; and, finally, 7) Learning through collaboration with teachers and external experts, referring to learning from social interaction with team members, other teachers within and outside the school, and interaction with scientists or workers in a specific field.

After coding the teachers’ professional learning activities, we first put all the different codes for each teacher together (divided into codes representing learning activities about subject matter contents and learning activities about teaching methods, related to the general PUSc. syllabus as well as to the specific topic of ‘the Universe’). Second, we compared the different combinations of codes across the teachers.
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Table 4.2 Categories of professional learning activities to be coded, with examples

<table>
<thead>
<tr>
<th>Category</th>
<th>Learning activity</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Doing</td>
<td>Unconscious learning activities</td>
<td>Practicing the act of teaching</td>
</tr>
<tr>
<td>Experiencing</td>
<td>Experiencing concrete ‘real life’ situations</td>
<td>Observation of phenomena (positions of moon, sun, stars)</td>
</tr>
<tr>
<td></td>
<td>Experiencing computer simulations</td>
<td>Manipulating and observing positions and movements of sun, moon, and planets</td>
</tr>
<tr>
<td></td>
<td>Experiencing students’ activities</td>
<td>Experiencing a student’s role as a debater in debating activities</td>
</tr>
<tr>
<td>Experimenting</td>
<td>Testing new materials</td>
<td>Testing a pre-module on a specific topic of the PUSc. programme</td>
</tr>
<tr>
<td></td>
<td>Preparing lessons individually</td>
<td>Designing a (series of) lesson(s) on a specific topic</td>
</tr>
<tr>
<td></td>
<td>Experimenting with new teaching approaches</td>
<td>Trying out new didactical approaches, such as the Jigsaw method, or pedagogical approaches, such as guiding and supervising students’ learning processes rather than lecturing,</td>
</tr>
<tr>
<td></td>
<td>Constructing lesson materials</td>
<td>Constructing physical models or other concrete materials to promote students’ understanding of abstract issues</td>
</tr>
<tr>
<td></td>
<td>Organizing study visits for students</td>
<td>Developing activities to be done by students when visiting a museum, a university, or an industrial company.</td>
</tr>
<tr>
<td>Information gathering</td>
<td>Studying the subject matter literature</td>
<td>Reading (academic) study books on unfamiliar topics, such as ‘genetic engineering’</td>
</tr>
<tr>
<td></td>
<td>Reading (professional) journals</td>
<td>Reading ‘NVOX’ (journal of the Dutch association for teachers in science)</td>
</tr>
<tr>
<td></td>
<td>Studying teaching methods and manuals</td>
<td>Reading the ANWorrd teaching method or other PUSc. teaching methods (manuals)</td>
</tr>
<tr>
<td></td>
<td>Reading newspapers</td>
<td>Reading articles about scientific topics in relation to society</td>
</tr>
<tr>
<td></td>
<td>Reading students’ work</td>
<td>Reading students’ studies of specific topics</td>
</tr>
<tr>
<td></td>
<td>Attending professional conferences</td>
<td>Scanning external resources in professional conferences</td>
</tr>
<tr>
<td></td>
<td>Browsing the Internet</td>
<td>Surfing the Internet in order to collect information about new content or teaching approaches, or looking for classroom materials</td>
</tr>
<tr>
<td></td>
<td>Watching television</td>
<td>Watching news and current affairs programmes</td>
</tr>
<tr>
<td></td>
<td>Watching film and video (documentaries)</td>
<td>Watching film and video on unfamiliar topics, such as the ‘human immune system’</td>
</tr>
</tbody>
</table>

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4.4.2 Research question 2: Course of development

The aim of this part of the analysis was to produce a description of the courses of teachers’ competence development with regard to subject matter contents and with regard to teaching methods, pertaining to PUSc. and, specifically, to the subject of ‘the Universe’.

We analysed the frequencies and the combinations of professional learning activities the teachers were engaged in (according to their own stories) between their starting as teachers of PUSc. (in September 1998 or 1999) and the time that the Story-line method was conducted (September 2004), and their predictions of future engagement (from September 2004 to September 2007). This enabled us to describe the course of the teachers’ professional development in the first years of teaching the new syllabus, from their own point of view.
4.4.3 Research question 3: Changed competences

The aim of this part of the analysis was to answer the third research question, that is, how the teachers’ competences (with regard to subject matter contents and with regard to teaching methods, concerning PUSc. in general and, specifically, the subject of ‘the Universe’) changed over time. While the teachers were drawing their storylines, we asked them to evaluate their competences retrospectively and to describe those competences, and discuss how, in their view, these competences had changed over the course of time. After reading the teachers’ stories, we selected those comments in which they described their (changing) competences. Next, we summarized, for each teacher, in what respects his competences changed over the first five or six years of teaching the PUSc. syllabus. Finally, we compared the teachers’ changed competences (as reported by the teachers themselves) across the group of eight teachers.

4.5 Results

4.5.1 Research question 1: Professional learning activities

To answer the first research question, we put together, for each teacher, the various codes that we had assigned to his comments. To illustrate the way we coded the teachers’ statements, we first provide some clear coding examples related to professional learning activities from the different categories (i.e., doing, experiencing, experimenting, information gathering, reflecting, interacting with students, and collaborating with teachers and experts, Appendix 1). Sometimes, the codes were applied to comments about competence development (learning) in subject matter contents, and other times they were applied to comments about competence development (learning) in teaching methods (related to PUSc. or to the subject of ‘the Universe’).

In the second part of this section, we compare the number and combinations of applied codes across the eight teachers.

4.5.1.1 The coding of professional learning activities from diverse categories

Learning by doing

Professional learning activities in this category concern the learning of teaching methods simply by practicing the act of teaching.

T1:  “You just have to practice to learn to use them (different teaching methods)”
    [Teaching method; PUSc./ the Universe]
    Code: Doing

T4:  “Teaching improves with experience”
    [Teaching method; PUSc./ the Universe]
    Code: Doing
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T5: “Practice makes perfect, it all becomes easier”  
[Teaching method; PUSc./ the Universe]  
Code: Doing

Learning by experiencing

Learning by experiencing is understood as teachers’ practicing of new teaching methods by taking the role of a student, and also teachers’ experiencing of specific topics in real-life situations (or in computer simulations).

T4: “We were sort of like pupils (during the Introductory course) and just by experiencing the teaching method I realized, ‘Hey, that’s fun’”  
[Teaching method; PUSc./ the Universe]  
Code: Experience(activ)

T2: “A colleague of mine took me to the Belgian Ardennes to look for fossils. If you’ve never actually seen a fossil and you have to teach about them, you really can’t get into it (as well)”  
[Subject matter; PUSc.]  
Code: Experience(real)

T8: “Well, to understand the phases of Venus, just take ‘Red shift’ (i.e., a computer simulation programme), and look at Venus on a particular day, and the next day, and the next, and in the evening of that day again…and look what happens then…. it is really astonishing”  
[Subject matter; the Universe]  
Code: Experience(comp)

Learning by experimenting

This form of learning concerns teachers’ experimentation with (and improvement of) new instructional tools and techniques. Experimenting with concrete materials to explain abstract issues to students also increases teachers’ own understanding of the subject matter.

T5: “Small things count, like how I arrange the tables during a House of Commons-like debate. Or how I use the blackboard, or where I am myself, standing or sitting”  
[Teaching method; PUSc./ the Universe]  
Code: Experm(teachapp)

T8: “Finding or producing suitable materials for a certain topic, or a good videotape…for example, if I want to understand a topic like the immune system I have to visualize it and think in metaphors such as adaptors, to get a good grip on it myself”  
[Subject matter; PUSc.]  
Code: Experm(material); Code: Experm(lesson)
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Learning by information gathering

This category of learning activities refers to teachers’ scanning and gathering of information from external sources, such as professional journals and other educational publications, to learn about recent developments and research in relevant content areas. This also includes browsing the Internet and attending professional conferences to find new instructional ideas and materials. Finally, reports and questions in the daily news offer teachers up-to-date contexts to use in their lessons.

T1: “By preparing lessons and reading up on the topic, I really increased my expertise in the subject matter”
[Subject matter; PUSc./ the Universe]
Code: Info(subject)

T5: “My daily newspaper has a section devoted to science on Fridays. So on Fridays I got up early and nine times out of ten I would find something in the paper to start my lesson with”
[Subject matter; PUSc./ the Universe]
Code: Info(papers)

T3: “I have been doggedly keeping up with new developments in my subject in the news. I continually increase my knowledge because I keep up the reading”
[Subject matter; PUSc./ the Universe]
Code: Info(subject); Code: Info(papers); Code: Info(journals)

Learning by reflecting individually

This form of learning refers to teachers’ reflection-on-action as a basis for knowledge and skill development. This reflection is usually solitary in nature. Teachers’ reflection consists of thinking deeply, for example, about a completed lesson. They especially reflect on things that went wrong. Learning by systematic reflection following a particular model (cf. ‘ALACT’, Korthagen & Kessels, 1999) was not found in the data.

T8: “I’ve not done a good job when pupils really don’t get what I mean when I ask questions like ‘Why are the observations about the phases of Venus along with its relative size the main arguments in favour of the heliocentric model?’ This makes me feel dissatisfied with my teaching and with the teaching materials I’ve been using”
[Teaching method; the Universe]
Code: IR(lesson)

T4: “Some groups just won’t get started (on the work). I don’t like that at all, so it really makes me wonder (why)”
[Teaching method; PUSc./ the Universe]
Code: IR(studatt)

T4: “If I find that the answers my pupils give just miss the most important points, that really makes me think in more depth about the topic”
[Subject matter; PUSc./ the Universe]
Code: IR(studwork)

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Learning by interacting with students

Learning in this category is related to teachers’ interactions with small groups of students who are participating in diverse classroom activities. Two-way communication makes it possible to adapt a way of teaching to the students’ needs and abilities.

T5  “I really like to talk to young people (…) about their motives. So what I like to do is just to sit down with my class or have a classroom discussion about how PUSc. relates to their own lives. I take it from there to introduce the topic of the lesson and their assignments”
[Teaching method; PUSc./ the Universe]
Code: Int(students)

Learning by collaborating

Teachers’ collaboration or collegial interaction (storytelling, helping, sharing, joint work) differs in the extent to which they depend on each other in this interaction, as can be concluded from their comments. Teachers are most dependent in ‘joint work’; ‘storytelling’, on the other hand, requires almost no interdependence. Teachers who are involved in joint work reflect together on their work but, as in individual reflection, a specific plan or model is not followed.

T2:  “I share a free period with another PUSc. teacher, so each week we sit down together and discuss our experiences. Another colleague, T., always asks us afterwards what we have decided to do. But actually, we never take decisions (during these discussions)”
[Subject matter/ Teaching method; PUSc./ the Universe]
Code: Coll(teach/exp)story

T4:  “We really share the work, according to our own subject. We share materials and the workload of producing tests, so everybody pitches in, but we don’t go around checking on each other’s work”
[Teaching method; PUSc./ the Universe]
Code: Coll(teach/exp)share/mat

T2:  “I share my experiences by mail, all of us do: tips like how long an activity takes, organizational things. It really helps to share; I don’t blame myself if something goes wrong when I realize it was due to the organization (of the lesson)”
[Teaching method; PUSc./ the Universe]
Code: Coll(teach/exp)share/idea

T5:  “I share two groups of pupils with my colleague. So we have to discuss things. Team teaching a class really means you have to communicate a lot about the subject matter”
[Subject matter; PUSc./ the Universe]
Code: Coll(teach/exp)joint/ co-t
4.5.1.2 Combinations of professional learning activities

After reading the teachers’ stories and coding all their relevant comments, we collected the codes applied per teacher. We found that, in general, professional learning activities that helped in developing competences in teaching methods and in subject matter contents (with regard to the entire PUSc syllabus and to the specific subject of ‘the Universe’) were not similar (e.g., the activity of ‘experimentation’ was often connected with teaching methods, and the activity of ‘information gathering’ with subject matter contents). At the same time, similarities were found between the combinations of activities related to the competence developments in PUSc and in the subject of ‘the Universe’ (both for teaching methods and subject matter contents).

Considerable differences were found in the numbers and combinations of professional learning activities across the teachers. Below, by way of illustration, we discuss the results that contrasted most, that is, the results for Teacher 1 (T1) and Teacher 3 (T3). See Table 4.3.

Table 4.3 Comparison of the coding of the professional learning activities of T1 and T3

<table>
<thead>
<tr>
<th>Codes T1</th>
<th>Subj.matter PUSc.</th>
<th>Subj.matter ‘the Universe’</th>
<th>Teaching methods PUSc.</th>
<th>Teaching methods ‘the Universe’</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experm(lesson)</td>
<td>Experm(lesson)</td>
<td>Experm(teachapp)</td>
<td>Experm(teachapp)</td>
<td></td>
</tr>
<tr>
<td>Experm(material)</td>
<td>Experm(material)</td>
<td>Doing</td>
<td>Doing</td>
<td></td>
</tr>
<tr>
<td>Info(studybooks)</td>
<td>Info(studybooks)</td>
<td>Coll(teach/exp)/share/mat</td>
<td>Coll(teach/exp)/share/mat</td>
<td></td>
</tr>
<tr>
<td>Info(papers)</td>
<td>Info(papers)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Codes T3</th>
<th>Subj.matter PUSc.</th>
<th>Subj.matter ‘the Universe’</th>
<th>Teaching methods PUSc.</th>
<th>Teaching methods ‘the Universe’</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experm(test)</td>
<td>Experm(test)</td>
<td>Experm(teachapp)</td>
<td>Experm(teachapp)</td>
<td></td>
</tr>
<tr>
<td>Info(papers)</td>
<td>Info(papers)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Info(journals)</td>
<td>Info(journals)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Info(lectures)</td>
<td>Info(lectures)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Info(rs)</td>
<td>Info(rs)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coll(teach/exp)</td>
<td>Coll(teach/exp)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- share/mat</td>
<td>- share/mat</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>- ref/teach</td>
<td>- ref/teach</td>
<td></td>
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<td></td>
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<tr>
<td>- joint/writ</td>
<td>- joint/writ</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- joint/comm</td>
<td>- joint/comm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coll(teach/exp)</td>
<td>Coll(teach/exp)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- share/mat</td>
<td>- share/mat</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- ref/teach</td>
<td>- ref/teach</td>
<td></td>
<td></td>
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<tr>
<td>- joint/writ</td>
<td>- joint/writ</td>
<td></td>
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<tr>
<td>- joint/comm</td>
<td>- joint/comm</td>
<td></td>
<td></td>
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<tr>
<td>- joint/whop</td>
<td>- joint/whop</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Teacher 1 (T1) learned relevant topics by reading study books and newspapers while he prepared his lessons in the diverse domains of PUSc and the subject of ‘the Universe’. He developed his competences in new teaching methods by experimenting
individually and practicing in the classroom. He developed new materials himself, but he also shared materials with other teachers. In order to code his professional learning activities, we applied seven codes (3x Experm, 1x Doing, 2x Info, and 1x Coll).

Teacher 3 (T3) learned relevant subject matter knowledge (PUSc. and ‘the Universe’) by testing experimental instruction materials, developing his own materials, much reading and other ways of information gathering, and collaborating with other teachers and experts (e.g., writing and editing one of the seven PUSc. teaching methods). T3 developed and improved his teaching methods by experimenting in the classroom and interacting with his students. Furthermore, he collaborated in teacher networks and communicated his findings to other PUSc. teachers nationwide. We used fourteen codes to code his professional learning activities (2x Experm, 4x Info, 1x Int, and 7x Coll).

In Table 4.4, we show another teacher’s results (Teacher 4) that were in between the results of T1 and T3. The codes reflecting Teacher 4 (T4)’s professional learning activities indicate that he probably learned less individually than T1 did but, on the other hand, not as collaboratively as T3 (see Table 4.3). In order to code T4’s learning activities, we applied fourteen codes (3x Experm, 1x Experience, 1x Doing, 4x Info, 2x IR, and 3x Coll). It is remarkable that the codes for his competence development concerning the subject matter of PUSc. (in general) differ from those for the content of ‘the Universe’ (first and second columns, Table 4.4), indicating his engagement in different professional learning activities with regard to PUSc. and to the subject of the Universe.

Table 4.4 T4: The coding of his professional learning activities

<table>
<thead>
<tr>
<th>Codes</th>
<th>Subj.matter PUSc.</th>
<th>Subj.matter ‘the Universe’</th>
<th>Teaching methods PUSc.</th>
<th>Teaching methods ‘the Universe’</th>
</tr>
</thead>
<tbody>
<tr>
<td>T4</td>
<td>Experm(lesson)</td>
<td>Doing</td>
<td>Doing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Experm(material)</td>
<td>Experience(activ)</td>
<td>Experience(activ)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Experm(teachapp)</td>
<td>Experm(teachapp)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Info(lectures)</td>
<td>IR(studart)</td>
<td>IR(studart)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Info(studybooks)</td>
<td>Coll(teach/exp)story</td>
<td>Coll(teach/exp)story</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Info(rework)</td>
<td>Coll(teach/exp)share/mat</td>
<td>Coll(teach/exp)share/mat</td>
<td></td>
</tr>
<tr>
<td></td>
<td>IR(studwork)</td>
<td>Coll(teach/exp)share/pract</td>
<td>Coll(teach/exp)share/pract</td>
<td></td>
</tr>
</tbody>
</table>

Teacher 4 (T4) learned new teaching methods by experiencing, that is, by practicing while taking the role of a student (e.g., at the Introductory course), and by experimenting and practicing in the classroom in combination with individual reflection on the students’ attitudes to his lessons. He also shared experiences and resources with other teachers (in and outside the school). He gained competences in relevant subject matter of PUSc. by attending lectures on conferences, reading study books, and reflecting on students’ work. With regard to the subject of ‘the Universe’, T4 learned relevant issues by reading up on the topic (using - the manuals of - different teaching methods), while preparing his lessons in this subject. We used
diverse codes reflecting collaborative activities (i.e., ‘storytelling’, ‘sharing’), but the code of ‘joint work’ was not applied.

How long the teachers were engaged in the different combinations of learning activities, and whether the construction of these combinations of activities changed over time, is discussed in the next section, in which the course of development of the teachers’ competences is described.

4.5.2 Research question 2: Course of development

In analysing the frequencies and the combinations of professional learning activities the teachers were engaged in between 1998 (1999) and 2004 (and extrapolating from 2004 to 2007), three typical ways of development were found: 1) revolutionary development followed by continuing small growth or stabilization; 2) evolutionary development which gradually slows down; 3) inconsistent or mixed development.

4.5.2.1 Revolutionary development

This type of development was typified by a certain period in which a teacher was engaged in a particular combination of learning activities, followed by a period in which the frequency and the number of activities decreased (rapidly). Teacher 2 expressed this as follows (see also Figure 4.1 about his development of competences over time, as an illustration).

![Figure 4.1 Revolutionary development; T2](image)

T2: “At first I had to prepare a lot of lessons and materials, and read a lot, I really had to. After a while it calmed down (...). I just have things running smoothly now; I have my own routines. I still use the same materials. They work well, so why should I change? I still do a lot of reading, but I’m not under so much pressure anymore”
4.5.2.2 Evolutionary development

This type of development was typified by a long period of engagement in a specific combination of professional learning activities. The frequency of the activities only slightly reduced over time. For Teacher 5 the development was as follows (see also Figure 4.2 about his development of competences over time).

![Figure 4.2 Evolutionary development; T5](image)

T5: “Learning by doing, and then afterwards, discussing things with my colleagues in the preparation room. My style of learning really is communicating with others. That hasn’t changed but it’s not as necessary as before. And I still read. You always have to read”
4.5.2.3 Inconsistent or mixed development

In analysing the teachers’ stories about the development of their competences, we also found (changes in) combinations and frequencies of professional learning activities that differed greatly with regard to the general PUSc. syllabus and the specific subject of ‘the Universe’. An example of such a development is a revolutionary, irregular, change regarding the PUSc. syllabus as a whole together with an evolutionary change in relation to the specific subject of ‘the Universe’ (see Figure 4.3, which shows the story-lines of Teacher 4 (T4) in illustration of this).

![Graph showing inconsistent or mixed development](image)

*Figure 4.3 Inconsistent and mixed development; T4*

Teachers developed their competences in PUSc. and the specific subject of ‘the Universe’ (subject matter contents and teaching methods) in the above-mentioned ways in their first five or six years of teaching the new PUSc. syllabus. In the following section, we discuss in what respect the teachers’ competences changed over this period of time (as reported by the teachers themselves).

4.5.3 Research question 3: Changed competences

The results of the analyses indicate that all teachers had developed their competences in the PUSc. syllabus and in the specific subject of ‘the Universe’ (both for subject matter and teaching methods) in the period under investigation, at least in their own perceptions.

We first discuss the results for the teachers who evaluated their competences as *insufficient* when PUSc. was first implemented in the school. We then discuss the results for those teachers who considered their competences to be *sufficient* from the start.
4.5.3.1 Insufficient competences at the start

Teachers who evaluated their competences (in subject matter contents and teaching methods) as insufficient at the start of teaching PUSc. (see the story-lines: scaling lower than a 3) reported a strong development of their competences over time. This generally meant that most of the gaps in their subject matter knowledge had been filled. They had also picked up diverse real-life applications (concrete examples, anecdotes, practical stories, and fascinating details of the subject matter). In addition, they had developed their competences in new teaching methods, instruction materials, and tools to make difficult and abstract issues concrete for students, as is illustrated by the following statement of Teacher 2 (T2).

T2: “When I taught chemistry I only knew three teaching methods: 1) lecturing, 2) assignments, and 3) practicals. Now (2004) I use all kinds of methods; I use lectures, individual and group work, quizzes, the Internet, practical assignments, pupil PowerPoint presentations, and posters. I also use (physical) models and simulations on the computer”

4.5.3.2 Sufficient competences at the start

Teachers who evaluated their competences (in subject matter contents and teaching methods) as sufficient when PUSc. was introduced (see the story-lines: scaling equal to or higher than a 3) in general indicated that their competences had developed slightly. They had maintained their subject matter knowledge, keeping alert to current developments (e.g., the discussion about ‘Intelligent Design’). The teachers did not aim to expand their repertoires of teaching methods. Instead, they refined, improved, adapted, or deepened the methods and techniques they already used. For instance, Teacher 3 (T3) stated:

T3: “Of course I have added a few things to my repertoire, like the expert method. But it’s really not that different from what I did before (in Biology). When I first taught here in 1974, my first year, …the idea of splitting up your class into small groups: one working on fish, one on reptiles, one on mammals, etcetera, and then having pupils explain and present, I was already doing that”

Teachers indicated having found or developed better examples, metaphors, and models to support the students’ learning processes. In addition, methods and techniques to make students actively construct their knowledge and understanding were used even more adequately, that is, they were connected with specific subjects and adapted to suit students of different ages and levels of education. As an example, Teacher 3 (T3) reported:

T3: “I have my pupils do a lot of group work in which they have to communicate with each other: discussion, debate, expert method, forum,…I have learned

---

1 The expert method or Jigsaw method provides a method of organizing school learning to facilitate communication activities among students. In it, students break into groups, each of which learns about a different topic. The students regroup so that there is one expert on each topic in each group, and the students then teach each other about all topics (Greeno, Collins, & Resnick, 1996).
Experienced science teacher’s learning…

(…) to adapt these for HAVO pupils, and pupils from the ‘humankind and society’ streams. Lots of structure, help, and coaching really support these pupils in learning in more depth; otherwise, they’re just lost”

Teachers also mentioned the process of knowledge integration and internalisation over time, as described by Teacher 6 (T6).

T6: “At first you have all the knowledge about the subject matter or teaching methods in your head, so you have to think to be able to use it. Now I know it through and through, so I can sort of juggle it around”

4.5.3.3 Different (mixed) competences, at the start

Teachers who evaluated their competences in the subject of PUSc. in general and in the specific subject of ‘the Universe’ as different at the start of PUSc. indicated that, in 2004, they had not gained as many competences in the subject of PUSc. and in the subject of ‘the Universe’, or had gained different competences in each subject (in subject matter contents as well as in teaching methods). Teacher 4 (T4), who started with more competences in the subject of ‘the Universe’ than in the general PUSc. syllabus, explained how, for him, subject matter knowledge and teaching methods were related in this regard. See also Figure 4.3.

T4: “When I know more about a topic I feel more comfortable. I can do whatever I want with ‘the Universe’, but other parts of the PUSc. curriculum are still not a piece of cake (for me)”

4.5.4 General research question

To answer the general research question (In what ways did experienced teachers in physics, chemistry, and biology learn in the workplace, in the context of the implementation of a new syllabus on Public Understanding of Science?), we summarized all outcomes of the three specific research questions, per teacher, in a table (see Table 4.5).

We then analysed the results so as to find any relationships between a teacher’s professional learning activities, course of development, and changed competences. We compared the relationships found, across the eight teachers, defining two qualitatively different types of learning, Type I and Type II.
### Chapter 4

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Professional learning activities</th>
<th>Course of development</th>
<th>Competence changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>7 code: 2x Experimenting 1x Experiencing 1x Doig 2x Information gathering 1x Collaboration (sharing)</td>
<td>Mixed; evolutionary in PUSc., revolutionary in ‘the Universe’</td>
<td>Implementation + improvement of concrete teaching methods. Learning of real-life subjects</td>
</tr>
<tr>
<td>T2</td>
<td>12 code: 2x Experimenting 3x Experiencing 1x Doig 2x Information gathering 4x Collaboration (sharing)</td>
<td>Revolutionary in PUSc. Revolutionary in ‘the Universe’</td>
<td>Implementation + improvement of concrete teaching methods. Learning of real-life subjects</td>
</tr>
<tr>
<td>T3</td>
<td>14 code: 2x Experimenting 4x Information gathering 1x Interaction with students 7x Collaboration (sharing+joint work)</td>
<td>Evolutionary in PUSc., Evolutionary in ‘the Universe’</td>
<td>Implementation + improvement of activating teaching methods, Refinement, adapting methods to different students, Learning of topical subjects</td>
</tr>
<tr>
<td>T4</td>
<td>14 code: 3x Experimenting 1x Experiencing 1x Doig 4x Information gathering 2x Individual reflection 3x Collaboration (sharing)</td>
<td>Mixed; revolutionary in PUSc., revolutionary in ‘the Universe’</td>
<td>Implementation + improvement of a mix of new (concrete and activating) teaching methods, Learning a mix of new (concrete and topical) subjects</td>
</tr>
<tr>
<td>T5</td>
<td>13 code: 3x Experimenting 4x Information gathering 1x Interaction with students 7x Collaboration (sharing+joint work)</td>
<td>Evolutionary in PUSc., Evolutionary in ‘the Universe’</td>
<td>Implementation + improvement of activating teaching methods, Refinement, adapting methods to different students, Learning of topical subjects</td>
</tr>
<tr>
<td>T6</td>
<td>16 code: 3x Experimenting 4x Information gathering 1x Individual reflection 8x Collaboration (sharing+joint work)</td>
<td>Mixed; revolutionary in teaching methods, Evolutionary in subject matter</td>
<td>Implementation + improvement of activating methods, Refinement, adapting methods to different students, Learning of topical subjects</td>
</tr>
<tr>
<td>T9</td>
<td>14 code: 2x Experimenting 1x Doig 4x Information gathering 1x Interaction with students 5x Collaboration (sharing+joint work)</td>
<td>Evolutionary in PUSc., Evolutionary in ‘the Universe’</td>
<td>Implementation + improvement of activating teaching methods, Refinement, adapting methods to different students, Learning of topical subjects</td>
</tr>
<tr>
<td>T8</td>
<td>16 code: 4x Experimenting 3x Experiencing 4x Information gathering 1x Individual reflection 4x Collaboration (sharing)</td>
<td>Mixed; revolutionary in PUSc., revolutionary in ‘the Universe’</td>
<td>Implementation + improvement of a mix of new (concrete and activating) teaching methods, Learning a mix of new (real life and topical) subjects</td>
</tr>
</tbody>
</table>
4.5.4.1 Type I

In this type of learning, teachers developed their competences in subject matter knowledge mainly individually by reading books, newspapers, and professional journals, using multimedia, attending professional conferences, and experiencing real-life issues or computer simulations (i.e., observing natural phenomena, such as fossils, eclipses of the sun and moon, and Venus’s phases). Teachers also developed their competences in teaching methods by experimenting and practicing individually in the classroom, individual reflection, sharing ideas, and exchanging materials and good practices with colleagues in and outside the school (e.g., via e-mail and at conferences).

The course of development was, in general, revolutionary and typified by a period of engagement in particular professional learning activities (i.e., activities in the working context that helped them in their professional development), followed by another period in which the teachers’ engagement in those activities decreased rather quickly.

In 2004, generally, most of the initial gaps in the teachers’ subject matter knowledge had been filled. The teachers had also picked up diverse real-life subject matter applications (e.g., concrete examples, anecdotes, practical stories). They had developed competences in various new teaching methods (i.e., group work, using multimedia), instruction materials, and tools to make difficult and abstract issues concrete for students.

Their teaching methods were characterized by variety (i.e., with regard to student activities), the use of concrete materials, and real-life contexts.

Teacher 1 (T1) and Teacher 2 (T2) represent this type of learning (see Table 4.5).

4.5.4.2 Type II

In this type of learning, teachers developed their competences in new subject matter knowledge mainly by reading books, newspapers, and professional journals, using multimedia, and attending professional conferences, and by social interaction with external experts. Teachers developed their competences in teaching methods by individual experimentation in the classroom, interaction with students, and collaboration and communication with colleagues at school. In addition, they participated in teacher networks and communities of experts, nationwide.

The course of development was, in general, evolutionary. Over time, the teachers remained engaged in most of their professional learning activities (i.e., those individual and collaborative activities in the working context that helped them in their professional development).

In 2004, in most cases, teachers had picked up topical subjects (e.g., ‘Intelligent Design’). They had found or developed better examples, metaphors, and models to support their students’ learning processes. In addition, they had introduced and refined methods and techniques to help students actively construct their knowledge and understanding more adequately, that is, methods and techniques connected with specific subjects and adapted to suit students of different ages and levels of education,
and students with different interests. Their teaching methods were characterized by many ways of collaboration and discussion between students.

Teacher 3 (T3), Teacher 5 (T5), Teacher 6 (T6), and Teacher 7 (T7) represent this type of learning (see Table 4.5).

Some teachers’ learning did not fit Type II or Type I, in particular that of Teacher 4 (T4) and Teacher 8 (T8). Both, T4 and T8, are experienced teachers of physics. Professional learning activities such as individual experimenting, experiencing and practising in the classroom, reading, individual reflection, and sharing stories, resources, and good practices typify their learning, like Type I learning. Their course of development, however, was mixed and inconsistent with respect to PUSc. in general and the specific subject of ‘the Universe’. In 2004, generally, these two teachers had learned different new subjects and had introduced (and improved) teaching methods which do not have much in common.

4.6 Conclusions

We investigated the learning of a small group of science teachers in the context of the introduction of a new syllabus in upper secondary education in the Netherlands. We used the Story-line method to elicit the teachers’ perceptions of their learning experiences at work in their first years of teaching the new syllabus. The teachers’ learning in the workplace could be characterized by two types of learning, excluding the learning of two teachers whose professional development was characterized as inconsistent and mixed. In this section we discuss some general conclusions and some conclusions with regard to Type I and Type II learning.

4.6.1 General conclusions

From our findings, we conclude that all teachers developed their competences (in subject matter and in teaching methods) in the new PUSc. syllabus and the specific subject of ‘the Universe’, at least according to their own evaluations. The professional learning activities that six out of the eight teachers participated in appeared to be related to the ways in which their competences changed over time (i.e., Type I and Type II).

Another general conclusion is that all teachers learned - to some extent - from other teachers, sharing stories, help, materials, ideas, and good practices. In this respect, collegial interactions were a source for the autonomous work, and autonomous initiatives often led to meaningful collegial contacts, in and outside the school (cf. Clement & Vandenberghe, 2000).

4.6.1.1 Type I

We conclude that the teachers representing Type I learning appeared to have

1. been involved in revolutionary development through engagement in mainly individual activities in the working context;
Experienced science teacher’s learning …

2. had insufficient competences in the subject of PUSc. in general and the specific subject of ‘the Universe’ at the start of PUSc.;

3. introduced and improved teaching methods characterized by the use of concrete materials, and real-life contexts.

4.6.1.2 Type II

We conclude that the teachers representing Type II learning appeared to have

1. been involved in evolutionary development through participation in individual and collaborative activities in the working context;

2. already had sufficient competences in the subject of PUSc. in general and the specific subject of ‘the Universe’ at the start of PUSc.;

3. developed competences to connect teaching methods with specific subjects and adapt these methods to students of different ages and levels of education, and students with different interests;

4. introduced and improved teaching methods characterized by many [different] ways of collaboration and discussion between students.

4.7 Discussion

In this section we discuss the above-mentioned results from three perspectives.

In addition, we discuss the advantages and disadvantages of the Story-line method for investigating teachers’ learning in the workplace.

4.7.1 Different perspectives

One perspective from which the results of the present study can be viewed is that of the teachers’ different learning styles. Vermunt (1998) identified, in a study on the learning of university students, four different learning styles: meaning-directed, reproduction-directed, application-directed, and undirected. The teachers representing learning Type I (individual engagement in professional learning activities) probably have a predominantly application-directed learning style. Characteristics of this learning style are the following: it should be possible to use knowledge so as to become a better professional, and studying means dealing with the material so that it becomes a part of oneself, as a result of which it is possible to make links between it and everyday life (Vermunt, 1998). In addition, it is possible that the teachers representing Type II teacher learning (participation in individual and collaborative learning activities) have a predominantly meaning-directed learning style. Characteristics of this learning style are the following: the person feels that he or she determines what should be learned and what insights are needed, the person studies in order to get to know things that interest him or her personally; the person wants to get to know the subject area, is curious, and wants to know everything that he or she can understand (Vermunt, 1998). The perspective of different learning styles may explain the differences in the course of the
teachers’ professional developments. (See Conclusion 1: revolutionary development for Type I versus evolutionary development for Type II).

The remaining two teachers (not representing Type I or Type II) probably have an undirected learning style (i.e., not clearly oriented towards meaning, reproduction, or application). This may be due to these teachers not being able to determine what is important to learn, but in their case, it may also be related to the finding that they showed differences in their competences in the subject matter of ‘the Universe’ and in the science content of PUSc. in general. This may be related to the teachers’ background in the discipline of physics. In contrast to the content of other subjects of PUSc. (e.g., ‘Life’ and the ‘Biosphere’), which are closer to the disciplines of biology and chemistry, the content of ‘the Universe’ was probably already familiar to these teachers at the start. Moreover, the teachers’ relevant subject matter knowledge appeared to be related to their teaching methods. In this regard, one teacher stated, “When I know more about a topic, I feel more comfortable. I can do whatever I want with ‘the Universe’, but other parts of the PUSc. curriculum are still not a piece of cake (for me)”, see section 4.5.3. This is consistent with conclusions from previous research (Sanders, Borko, & Lockard, 1993), which made clear that, when teaching outside their science specialty area, and when familiar with the topic, science teachers tend to plan more student-centered activities and conversational risky settings. Like novice teachers, they tend to rely on less risky instructional activities when they are less familiar with the topic.

A second perspective from which to explain the results of the study is that of the teachers’ different stages of ‘concern’ development (cf. Fuller, 1969). From this perspective, teachers representing Type II learning probably have reached a further stage of development than the teachers representing Type I. Specifically, the teachers representing Type II seemed to have reached the last stage, that is, the stage of student concerns, while teachers representing Type I (like pre-service teachers) may be still in the earlier stages of development, that is, mainly focusing on self concerns and task concerns. Two teachers (not representing Type I or Type II) may have reached an intermediate state between the other teachers (Types I and II). The Fuller model stipulates that appropriate (pre-service and) in-service experiences are essential to the passage of teachers through these phases of concerns (Pigge & Marso, 1997). However, research in this area has indicated that it is not evident that all Type I learners will eventually reach the final stage of the Type II learners. The perspective of different stages of development may explain the differences in the teachers’ competences in subject matter contents and teaching methods. (See Conclusion 2, Type I and Conclusions 2 and 3, Type II).

A third perspective from which to describe the outcomes of the study is that of the teachers’ different pedagogical knowledge and beliefs, and educational goals for PUSc. From this perspective, teachers representing Type I probably see learning as dealing with concrete experiences (cf. experiential learning, Kolb, 1984), and connecting knowledge with everyday life, that is, learning in relevant life-world contexts, aiming to have their students learn the subject matter of PUSc. in this way. Teachers
representing Type II possibly hold a social constructivist view on knowing and learning, as a result of which they aim to have their students learn the subject matter of PUSc. through classroom activities which support their active construction of knowledge and understanding in social interaction with other students. From this perspective, the other two teachers (not representing Type I or Type II) may have adopted not very explicit pedagogical knowledge and beliefs, and educational goals for PUSc. The perspective of different knowledge and beliefs, and goals, may explain the differences in the character of the teaching methods the teachers developed and improved over time. (See Conclusion 3, Type I, and Conclusion 4, Type II).

To gain more insight into the teachers’ learning in the context of education, research into these perspectives and how they are related to teachers’ learning and to each other is recommended.

4.7.2 Evaluation of the use of the Story-line method

In contrast to the use of interviews (cf. Kwakman, 2003; Lohman & Woolf, 2001; Van Eekelen, 2005), the Story-line method appeared to be a relatively easy way to get teachers to talk about their participation in professional learning activities and the development of their competences. Teachers evaluated their professional learning activities and competences themselves, which is a difficult task for a researcher to do. The stories about their professional learning activities and competence development, however, yielded qualitative data that had to be categorized and interpreted by the first and second authors. In contrast to the keeping of an electronic diary (cf. Van Eekelen, 2005), story-lines are relatively quick and easy to make, and can, therefore, be used to evaluate a teacher’s learning over a longer period of time. The Story-line method is selective in that it focuses on what is really found relevant to teachers. We acknowledge, however, the subjectivity of this method of evaluating important experiences. One disadvantage of the Story-line method (unlike an electronic diary) is that the information collected can be too general or may fail to do justice to relevant detail (Gergen, 1988).

4.7.3 Implications

With this study, we also aimed to generate ideas that can be used in supporting and coaching teachers’ execution of future innovations in science education. Based on the results of our study, we suggest the following initiatives for teachers’ professional development in the workplace.

1. Given our finding that teachers learned in qualitatively different ways, interventions should take differences between teachers, in terms of preferred learning activities, and already acquired competences, as a starting point, rather than adopting a ‘one size fits all’ approach which seems common in in-service training programmes.

2. As all teachers appeared to share stories, help, materials, ideas, and good practices with other teachers (and external experts), interventions could
involve teachers’ participation in diverse activities of sharing (resources, support, etcetera).

3. As teachers’ learning may be related to learning styles, stages of professional development, and pedagogical perspectives and goals for PUSc, interventions could start from teachers’ participation in systematic reflection on their own way of learning, stage of development, and pedagogical beliefs and educational goals (cf. Schön, 1983, 1987; Fullan & Hargreaves, 1992; Calderhead & Gates, 1993).

4.8 References


Experienced science teacher’s learning …


Chapter 4


Appendix I

Storyline method

Participants
Experienced teachers of biology, chemistry, and physics who had been teaching the new Public Understanding of Science syllabus since 1998 or 1999.

Goal
To measure the development in teachers’ competences in subject matter contents and teaching methods related to the subject of PUSc. in general and to the specific subject of ‘the Universe’ between September 1998 (1999) and September 2004, from their own evaluations,

Procedure
An individual interview was conducted with each teacher, using an audio cassette recorder and standardised graphs to draw the story lines in.

A. Competences in subject matter content for PUSc.
Please, scale (graph I) your competences in the subject matter content for PUSc. at this period of time (September 2004).
  • Explain your scaling.
Scale your competences in the subject matter content for PUSc in September 1998 (1999).
  • Explain your scaling.
Draw a line symbolizing the course of development of your competences between these two moments in time (line a).
  • Comment aloud on your drawing.
Continue the line to the year 2007 (when the content and organization of PUSc. will be changed).
  • Explain your scaling.

Please, repeat the procedure for the competences in subject matter content for the specific subject of ‘the Universe’.

B. Competences in subject matter content for the specific subject of ‘the Universe’
(graph II, line b).

Please, repeat the procedure for the competences in teaching methods for PUSc.

C. Competences in teaching methods for PUSc.
(graph III, line c).
Please, repeat the procedure for the competences in teaching methods for the specific subject of ‘the Universe’.

D. Competences in teaching methods for the specific subject of ‘the Universe’.
(graph IV, line d).
## Appendix II

### Categories of learning activities, and codes

<table>
<thead>
<tr>
<th>Category</th>
<th>Learning activity</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Doing</strong></td>
<td>Unconscious learning activities while practicing the act of teaching</td>
<td>Doing</td>
</tr>
<tr>
<td><strong>Experiencing</strong></td>
<td>Experiencing concrete real-life situations</td>
<td>Experience(realLife)</td>
</tr>
<tr>
<td></td>
<td>Experiencing computer simulations</td>
<td>Experience(computing)</td>
</tr>
<tr>
<td></td>
<td>Experiencing students’ activities</td>
<td>Experience(activities)</td>
</tr>
<tr>
<td><strong>Experimenting</strong></td>
<td>Testing new materials</td>
<td>Experm(test)</td>
</tr>
<tr>
<td></td>
<td>Preparing lessons individually</td>
<td>Experm(lesson)</td>
</tr>
<tr>
<td></td>
<td>Experimenting with new teaching approaches</td>
<td>Experm(teachapp)</td>
</tr>
<tr>
<td></td>
<td>Constructing lesson materials</td>
<td>Experm(material)</td>
</tr>
<tr>
<td></td>
<td>Organizing study visits for students</td>
<td>Experm(visits)</td>
</tr>
<tr>
<td><strong>Information gathering</strong></td>
<td>Studying the subject matter literature</td>
<td>Info(literature)</td>
</tr>
<tr>
<td></td>
<td>Reading (professional) journals</td>
<td>Info(journals)</td>
</tr>
<tr>
<td></td>
<td>Studying teaching methods and manuals</td>
<td>Info(meth/ma)</td>
</tr>
<tr>
<td></td>
<td>Reading newspapers</td>
<td>Info(papers)</td>
</tr>
<tr>
<td></td>
<td>Reading students’ work</td>
<td>Info(study)</td>
</tr>
<tr>
<td></td>
<td>Attending lectures / professional conferences</td>
<td>Info(lectures)</td>
</tr>
<tr>
<td></td>
<td>Browsing the Internet</td>
<td>Info(internet)</td>
</tr>
<tr>
<td></td>
<td>Watching television</td>
<td>Info(television)</td>
</tr>
<tr>
<td></td>
<td>Watching film and video</td>
<td>Info(vid/film)</td>
</tr>
<tr>
<td><strong>Reflecting individually</strong></td>
<td>Reflecting individually upon a lesson</td>
<td>IR(lesson)</td>
</tr>
<tr>
<td></td>
<td>Reflecting individually upon students’ work</td>
<td>IR(study/work)</td>
</tr>
<tr>
<td></td>
<td>Reflecting upon students’ attitude</td>
<td>IR(student)</td>
</tr>
<tr>
<td><strong>Interacting with students</strong></td>
<td>Getting in touch with and communicating with students</td>
<td>Int(students)</td>
</tr>
<tr>
<td><strong>Collaborating with teachers and external experts</strong></td>
<td>Story telling</td>
<td>Coll (teach/exp)/story</td>
</tr>
<tr>
<td></td>
<td>Asking/giving help</td>
<td>Coll (teach/exp)/help</td>
</tr>
<tr>
<td></td>
<td>Sharing a) good practices; b) materials; c) ideas about innovation</td>
<td>Coll (teach/exp)/share/pract.</td>
</tr>
<tr>
<td></td>
<td>Reflecting with a) team members; b) other teachers; c) experts</td>
<td>Coll (teach/exp)/share/idea</td>
</tr>
<tr>
<td></td>
<td>Joint work a) joining a committee in or outside the school; b) preparing lessons or a curriculum; c) making agreements about the implementation of an innovation; d) co-teaching; e) writing a teaching method; f) preparing and leading a workshop</td>
<td>Coll (teach/exp)/joint/comm.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Coll (teach/exp)/joint/lesson</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Coll (teach/exp)/joint/innov</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Coll (teach/exp)/joint/co-t</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Coll (teach/exp)/joint/writ</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Coll (teach/exp)/joint/whop</td>
</tr>
</tbody>
</table>