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Inferring the pedagogical content knowledge and the pedagogical knowledge of two French chemistry teachers from the study of their activity

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Abstract

The teacher's activity in the classroom relies upon both the determinants of the teaching learning situation (the students, the content-to-be-taught, the syllabus...) and the teacher's beliefs and knowledge. This study addresses the activity of two teachers working on the same subject, the spontaneous evolution of chemical systems in a 12th grade form. During a training session aiming to develop the teachers' professional knowledge of this topic (content knowledge, CK and pedagogical content knowledge, PCK), each teacher presented his/her lesson plan and goals before implementing them. Then each teacher watched his/her own classroom video to comment and discuss his/her choices and actions and the students' behaviour. Analysis of the enactment of the lesson plan shows the experienced woman teacher's classroom management offered the students more opportunities to express their reasoning. She could reflect on her students' reasoning and display various types of knowledge by commenting her actions while watching the video: pedagogical knowledge, PK, and knowledge of students' difficulties and knowledge of instructional strategies to overcome these difficulties which are two components of PCK. The less experienced teacher expressed limited professional knowledge (whether CK, pedagogical knowledge, PK or PCK). The discussion will propose some reasons for this.

Long paper

This paper is based on the study of the activity of two chemistry teachers working on the same topic during a single classroom session and seeks to highlight the decisions they make both when planning their session and during the implementation of the lesson plan.

Framework

The teacher's activity in the classroom relies upon both the determinants of the teaching learning situation (the students, their state of mind, the content-to-be-taught, the syllabus, the school...) and the teacher's beliefs and knowledge. Analysing the activity in the classroom is done following the methodological framework of the double didactic and ergonomic approach (Robert & Rogalski, 2002; Vandebrouck, 2013), and the teachers' professional knowledge according to the Shulman's typology (1987). The teacher's activity includes all that he/she does or does not, all that he/she says or does not (Robert, 2008) to achieve his/her tasks: promoting the learning of a given topic and designing the learning environment. Analysing the teacher's work means taking the constraints he/she faces into account.

According to this framework five dimensions structure the analysis of the activity: i) the cognitive dimension concerns the design of the tasks given to the students, the lesson plan and the chemical

content involved, ii) the mediative dimension concerns the implementation of the lesson plan paying particular attention to the choices of classroom organisation and of students' scaffolding, iii) the institutional dimension examines how the teacher takes the syllabus and the resources into account, iv) the social dimension is about the relationships with the people working in the school and the way the teacher takes the students' social background into account, v) and the personal dimension revolves around the teacher's conceptions of chemistry, chemistry teaching and the impact of his/her personal experience on his/her beliefs. Attaining these dimensions is made possible by analyzing the tasks proposed to the students and the lesson plan on one hand and the implementation of the lesson plan on the other hand. The latter analysis pinpoints the work organisation in the classroom, the relationships between the teacher and the students, the kind of help and the feedback the teacher gives to the students.

To characterise the teacher's knowledge two models are used, the Morine-Dershimer and Kent's model for pedagogical knowledge (PK) (Morine-Dershimer & Kent, 1999) and the Magnusson, Krajcik and Borko's model for pedagogical content knowledge (PCK) (Magnusson et al., 1999). Among PK, Corrigan (2009) considers three facets (or components), instructional models and strategies (PK-strategy), classroom management and organisation (PK-management), and classroom discourse and communication (PK-discourse), that should be mastered by the beginning teachers to attain higher professional development stages. The PCK model (Magnusson et al., 1999) includes five components. The first one, orientation to science teaching shapes the others, knowledge of curriculum (PCK-programme), knowledge of assessment (PCK-assessment), knowledge of students' understanding of the chemistry topic under consideration (PCK-student), knowledge of instructional strategies (PCK-strategy) that enable the students to overcome their difficulties. The content knowledge (CK, here the knowledge of the topic evolution of chemical systems) constitutes a separate domain of knowledge apart from PK and PCK but influences the PCK domain.

According to literature reviews, PCK-strategy and PCK-student on one hand (Van Driel et al., 1998) and PK-strategy and PK-management on the other hand (König et al., 2011) are the core components of PCK and PK respectively.

Making a clear difference between PK-strategy and PCK-strategy is crucial to categorize knowledge. PK-strategy concerns the design of tasks, their structure and diversity without taking the content into account, and the teacher's goals. If these goals and tasks can be expressed in the same manner for another chemistry or physics course, then they will be ascribed to PK-strategy. PCK-strategy denotes a strategy devoted to overcome a topic-specific learning difficulty. PK-management includes time management (time left for thinking, for achieving tasks), distribution of tasks among the students, establishing routines.

The teacher's activity in the classroom results from decisions taken during the planning and during the implementation (Wanlin & Crahay, 2012). These decisions depend on the teacher's knowledge, on the constraints he/she faces and on the results of his/her actions. The tasks and lesson plan design (cognitive dimension) entails choosing a global pedagogical strategy (PK-strategy) and rely on chemistry content knowledge (CK), curriculum knowledge (PCK-programme), knowledge of the students' understanding of the topic (PCK-student) and knowledge of specific methods suiting the cognitive goals to be achieved (PCK-strategy). The enactment of the course project (mediative dimension) includes the classroom organisation and the students' scaffolding which rest upon

knowledge of instructional strategies (PK-strategy) and of topic-specific strategies (PCK-strategy), of the students (PCK-student), of how to communicate with the students (PK-discourse) and of classroom and time management (PK-management).

Objectives and research questions

This presentation addresses the activity of two teachers (an experienced teacher and a beginning teacher) working on the same subject, the spontaneous evolution of chemical systems in a 12th grade form in France. During a training session aiming to develop the teachers' professional knowledge of this topic (CK and PCK), the trainees were invited to present their lesson plan and goals before implementing them. Two teachers presented their project and then each teacher was filmed during the implementation of the project. Thereafter, each teacher watched his/her own classroom video to comment and discuss his/her choices and actions and the students' behaviour. Given their different teaching experience, it appeared interesting to determine whether this difference could be noticed in their activity and how. As outlined above, the teacher's activity may be characterised by the decisions he/she makes. This presentation focuses on the knowledge that supports the decisions and intends to answer the following research questions:

Which components of teacher professional knowledge is it possible to identify?

Is there a type of knowledge more developed in the experienced teacher than in the beginning teacher?

Methodology

The teachers were briefly interviewed before and after their classroom session and were told to comment their classroom video some weeks later. The classroom sessions (words, gestures and movements) and the interviews were transcribed. The labwork sheet (if it exists) or the session (the course project is reconstructed) were analysed in terms of tasks given to the students. The classroom session transcript was split in episodes, which are delimited by the completion of a task. In each episode, the classroom organization was categorised specifying the role of the teacher and of the students. This first stage seeks to reveal the work organization enabling to determine the pedagogical strategies involved. The interactions between the teacher and the students are studied to set out the verbal exchanges, the kind of help and the feedback given by the teacher. For the second stage, the interviews are read thoroughly and confronted to the classroom transcription to note the comments about the implemented strategy, the classroom management and the students' difficulties, reasoning or actions. Thus, the knowledge inference takes place in two complementary stages.

Results

Let us call the experienced teacher, Dora (10 years' teaching experience and 4 in grade 12) and the less experienced teacher, Bud (2 years' teaching experience and none in grade 12).

Nature and organization of tasks

Bud gives out a labwork sheet with all the instructions to perform the experiments, the chemical equation involved and the questions to be answered. Dora does not and gives information step by

step. Dora's lesson relies on a single experiment whereas in Bud's labwork sheet five experiments are proposed, the last one is the same as Dora's. Bud's students have to perform the experiments, observe and interpret the observations (colour changing, precipitate formation, pH measurement in the 5th experiment) and answer a list of questions (5th experiment). Before they carry out a mixture of solutions (two acids and two bases), Dora's students have to write a chemical equation, then to express the chemical species concentrations in the mixture, after which, they have to predict what could happen in the mixture and why, before making a pH measurement.

In Bud's labwork sheet no prediction is asked, whereas it is possible. Bud's pedagogical strategy is classical and inductive: performing experiment, observation, answering or interpreting. On the contrary Dora prompts the students to reflect before manipulating, to elicit their ideas and even put forward hypotheses. Dora's students are engaged in a hypothetical-deductive approach. Obviously both teachers did not make the same choices to plan their lesson, revealing their different PK.

Work organization in the classroom

Both teachers alternate between different stages: explanation stages when they speak without questioning the students, collective dialogue stages when they question different students, students working in pairs stages. Dora also leads individual research stages while the students are reflecting silently to answer the questions and sometimes explain their reasoning in hushed voices if she comes to their table. Both teachers share some PK-management but not all of it.

Students' scaffolding

Bud corrects the students' practical gestures when they are manipulating whereas Dora tries to understand their conceptual difficulties and asks questions. She wants to know the reason why they wrote such chemical equation or said that nothing will happen because all the chemicals (written in the chemical equation) are present in the mixture right from the beginning (PCK-student). She holds detailed discussions, answering each argument (PCK-strategy) to modify these ideas.

Analysis of the interviews

Before the session Bud cannot predict the students' difficulties and does not notice them in the video (lack PCK-student) whereas his students encountered the same difficulties to express the chemical species concentrations as Dora's students. He just expects the students have forgotten what the reaction quotient is. However, a low-achiever student gives the correct expression of this quotient responding to Bud's question and Bud makes no comment (lack PCK-student). Watching a student pair who did not mix the right solutions, he admits he could have asked the other students to correct their mates instead of saying what was wrong (PK-strategy). He recognizes that he should have split the students in two groups, each group making a single pH measurement to gain time (PK-management). He says that when he moves near the students working in pairs, they feel confident and dare to ask questions (PK-management). Watching his classroom video, Bud mentions several times that he lacks perspective and makes some comparisons with what he thought or did when he was at school or at university. Bud says he often reads his notes during the session, which is a sign that he lacks confidence and perhaps CK. He struggles to adopt a teacher posture continuously.

Before the session, Dora predicts several conceptual difficulties for the students; in particular she claims that they will think that nothing happens in the mixture made from equal volumes of acids

and bases solutions (PCK-student). During the session, that idea (which was expressed) encourages the students to put forward a hypothesis (PCK-strategy). After the session she regrets not having given a printout with the names of the chemical species, (PK-management) because she was constrained to split the task in micro tasks (PK-strategy) to compensate for this lack. Watching the video, she explains the students' errors enabled her to uncover incorrect lines of reasoning she did not suspect (PCK-student). She stresses the students cannot calculate the species concentrations in a mixture. During the session, seeing this difficulty she interrupted the students' task and asked them to perform the experiment (PK-strategy). She says this change responds to a need, helps the students imagine what is at stake and boosts the rhythm of the session (PK-management). Dora states she encounters a dilemma: either let each student reflect on his/her own production and then to support him/her or choose a particular student's response and guide them together to reach the goal (PK-strategy).

Conclusion

Dora possesses more PCK than Bud. Moreover, she has a broader PK than Bud. Indeed, they used the same experiment extracted from the authors' syllabus booklet, but Bud implemented it in a classical manner whereas Dora included two tasks involving a specific students' cognitive reflection. The pedagogical strategy she chose enabled her students to express their reasoning and therefore contributed to the increase of her PCK-student because she discovered some new alternative ideas during this session. Bud may not feel confident enough to try such a strategy (he said "we will answer the questions together; I know it is not pedagogical"). Dora has already taught this programme and thus knows what topics it is worth spending time on to learn. Bud cannot rely on such knowledge nor ask his colleagues for advice because they do not teach this lesson.

Watching the video enabled both teachers to comment their actions but it appears that the less experienced teacher exhibited more PK than PCK. One possible reason for this is that PK is used in every classroom session whereas PCK is topic-specific and used in two or three classroom sessions per year. Thus PK can be frequently tested and is developed faster than PCK which needs several academic years to develop. Nevertheless student-centred pedagogical strategies seem to be a requisite to promote an increase of PCK, what implies to inform and convince pre-service teachers that all pedagogical strategies are not equivalent.

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