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**Title:**

**A chemistry teacher pedagogical content knowledge development through two lessons**

**Abstract** (296 words)

This paper examines a teacher's activity to reconstruct her choices and a part of her professional knowledge. Three dimensions of the teacher's activity are considered in this study: i) a cognitive dimension concerning the tasks given to the students and the chemistry content involved, ii) a mediative dimension regarding the unfolding teaching session, iii) a personal dimension including the teacher's knowledge and beliefs about chemistry and chemistry teaching. The teacher's activity in the classroom results from choices made during the design and the implementation of the lesson plan which depend among other on the teacher's knowledge and on the results of his/her actions. We assume that the comparison of two successive sessions of two groups of a same form provides indicators, modifications and unchanged features of the unfolding sessions, to infer pedagogical content knowledge (PCK) and pedagogical knowledge (PK). Our purpose is to determine them and to characterise the conditions and also PK that contribute to the development of PCK.

The data are two video-recorded successive sessions of a 12<sup>th</sup> grade form on the change criterion of chemical systems and of the teacher's interviews which took place just before and after the sessions. Several analyses follow: an analysis of the lesson plan to determine the tasks, of the unfolding teaching sessions to reveal the pedagogical strategies and the students' scaffolding, and of the teacher's comments to discover articulated knowledge. This first set of analyses provides tacit and expressed PCK and PK. The second analysis stage compares the two unfolding sessions and highlights the modifications that occurred, which are considered to be revealing the development of new PCK. A fine grain analysis of the chemistry content involved and of the classroom interactions allows to identify new PCK which also appear to be a consequence of PK involved.

**Extended summary** (1250 words exactly!)

This case study addresses a teacher's activity working on the change criterion of chemical systems in a 12<sup>th</sup> grade form. The purpose is to reconstruct some pedagogical content knowledge (PCK) and pedagogical knowledge (PK) from the analysis of the teacher's actions and choices.

The teacher's activity in the classroom relies upon the determinants of the teaching learning situation (students, content, syllabus, school...) and upon the beliefs and knowledge of the teacher. According to the framework of the double didactic and ergonomic approach (Robert & Rogalski, 2002; Vandebrouck, 2013) five dimensions structure the analysis of the activity.

The cognitive dimension concerns the design of the tasks given to the students, the lesson plan and the chemical content involved; the mediative dimension concerns the implementation of the lesson plan and especially the choices of classroom organisation and of students' scaffolding. Three other dimensions include determinants that influence the teaching learning situation. The institutional dimension examines how the teacher takes the syllabus, the resources, and the institutional constraints into account. 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. The personal dimension includes the teacher's conceptions, knowledge and beliefs about chemistry, chemistry teaching.

Inferring professional knowledge from the teacher's actions means that the focus is on the personal dimension, particularly on PCK and PK, and on the cognitive and mediative dimensions of the teacher's activity.

Drawing on the Morine-Dersheimer and Kent's model (1999) for PK, Corrigan (2009) highlights the role of three components, instructional models and strategies (PK-strategy), classroom management and organisation (PK-management), and classroom discourse and communication (PK-discourse). The PCK model (Magnusson et al., 1999) includes five components among which, knowledge of students' understanding of the chemistry topic under consideration (PCK-student) and knowledge of instructional strategies (PCK- strategy) that enable the students to overcome their difficulties. According to literature reviews, PCK-strategy and PCK-student on the 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.

The teacher's activity in the classroom results from decisions taken during the planning and the implementation (Wanlin & Crahay, 2012). They depend among other on the teacher's knowledge and on the results of his/her actions. The teacher's knowledge mobilized during actions is often tacit (Van Driel et al., 2001). Thus the analysis of actions leads to infer knowledge that is not articulated by the teacher. Nevertheless, an analysis of the teacher's comments on his/her actions provides expressed knowledge.

A chemistry teacher was filmed during two successive teaching sessions on the change criterion of chemical systems with the two groups of a 12<sup>th</sup> grade form in the same afternoon. She enacted a new lesson plan for the first time. The teacher's choices are analysed to determine the knowledge that supports the decisions. The comparison of the two successive sessions provides indicators, such as modifications of the unfolding sessions, which are assumed to be adaptations of actions and reveal new knowledge. The purpose is to determine PCK and PK inferred from the teacher's choices analysis, and the conditions and PK that contribute to the development of PCK.

### Methodology

The teacher (Dora) was briefly interviewed before and after the teaching sessions and was told to comment on her classroom videos some weeks later. She chose the second session.

A first analysis took place in three steps: i) the analysis of the lesson plan determined the tasks given to the students which informed about their nature and organisation; ii) the session transcript was split in episodes, each episode is delimited by the completion of a task, which revealed the work organisation enabling to determine the pedagogical strategies involved, and the interactions between the teacher and the students; iii) some comments made in the interviews led to infer knowledge and appreciate the reflexive ability of the teacher. The teacher's knowledge was actually inferred in each type of analysis. Then, the comparison of the two unfolding sessions revealed some modifications the reasons of which were examined in Dora's actions and comments and in some students' actions.

## Results

In both sessions the students had to predict what could happen in the mixtures (two acids and their conjugated bases), to write a chemical equation, to express the chemical species concentrations in the mixtures etc... Dora changed the tasks organisation from session 1 to session 2. She removed two tasks, modified the order and duration of others. See table 1.

In both sessions Dora adopted the same working modes: teacher's talks, collective dialogues, hands-on activities performed by students-pairs and students' individual reflection. Dora held detailed discussions to grasp the students' conceptual difficulties and let them express their arguments.

Dora commented on the students' understanding, on the unfolding sessions and gave some reasons for the changes she made. See table 2.

## Discussion

Dora's pedagogical strategy is student-centred and fruitful because the students expressed their ideas which, in turn, enabled Dora to make the problem solving progress and involve them in the process. Each session analyses provide tacit or expressed PCK and PK (see examples 1, 2 in table 2). The comparison of the two unfolding sessions shows that Dora's pedagogical strategy is stable (tacit PK), she used the same working modes but adapted some questions and some tasks orders (see examples 3, 4, 5 in table 2). These modifications result from reflection during action (Park & Oliver, 2008), and aim to avoid students misunderstandings and to provide a more direct way to the problem solving. The analysis of the modifications and of the associated comments supports the development of new PCK. It was made possible by the enacted student-centred strategy based on existing tacit PK and by the teacher's reflexive ability.

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	episode	duration	objective of the task	working mode		episode	duration	objective of the task	working mode
<b>group 1</b>	1	11min	<u>introducing the solutions</u>	teacher's talk and collective dialogue	<b>group 2</b>	1	6min30	introducing the mixtures to be made	teacher's talk
	2	4min	introducing the mixtures to be made	teacher's talk		2	7min	writing a chemical equation	students' reflection
	3	6min30	Looking for a possible chemical change	teacher's talk and collective dialogue		3	9min	reflecting on how to detect a chemical change	teacher's talk and collective dialogue
	4	7min	writing a chemical equation	students' reflection and collective dialogue		4	8min30	expressing the initial concentrations	students' reflection
	5	14min	making the mixtures	hands-on experiments in pairs		5	14min	making the mixtures	hands-on experiments in pairs
	6	13min	reflecting on how to detect a chemical change	teacher's talk and collective dialogue		6	14min	Looking for a possible chemical change	teacher's talk and collective dialogue
	7	7min	<u>expressing the equilibrium constant</u>	students' reflection and student correcting at the blackboard		7	11min30	how to use the pH value to determine the concentrations ratio in the final state	teacher's talk and collective dialogue
	8	11min	expressing the initial concentrations	collective dialogue and students' reflection		8	5min	measuring the pH	hands-on experiments in pairs
	9	8min30	expressing the initial reaction quotient	students' reflection and collective dialogue		9	17min30	calculating the concentrations ratio in the final state of the system	students' reflection and teacher's talks
	10	8min30	how to use the pH value to determine the concentrations ratio in the final state	teacher's talk and students' reflection		10	4min	expressing the initial reaction quotient	teacher's talk and students' reflection
	11	5min	measuring the pH	hands-on experiments in pairs					
	12	8min30	calculating the concentrations ratio in the final state of the system	students' reflection					

**twice underlined tasks are not proposed to group 2**

**table 1: episodes and tasks of the unfolding sessions**

	students actions	working mode	teacher actions	teacher comments during interviews			reconstructed PCK and PK
				before the unfolding session	in the following up interview	faced to the classroom video	
example 1	group 1: Vincent stated that a chemical change will occur in mixture 2 because the amount of the acids is different group2: Lucile made the same prediction based on the same reason	collective dialogue	1) prompted the students to explain why they think so 2) claimed that reason is an hypothesis that will be tested during the session 3) reminded that hypothesis when she recapitulated the problem to the students	I expect the students will say nothing happen in mixture 1 because all amounts are equal contrary to mixture 2	no comment	no comment or not watched	students predict a chemical change comparing the amount of species ( <b>expressed PCK-student</b> ) taking that idea into account is a way to involve the students solving the problem ( <b>tacit PCK-strategy</b> ) holding a detailed discussion with a student enables the expression of his/her reasoning ( <b>tacit PK-strategy</b> )
example 2	group2 : Chloé wrote four species on the left of the chemical equation and was wondering about the species she could write on the right.	individual reflection	1) asked for an explanation 2) tried to make the student change her mind leading a detailed discussion with her about the reactivity of the species	student's reasoning not anticipated	she wrote all species on the left of the chemical equation and did not know what to write on the right. I didn't expect that but it is logical they think so.	this mistake means the student doesn't imagine that some species will be consumed and some others will be produced	the students struggle to write a chemical equation when confronted to a system comprising all species about to react and to be produced ( <b>expressed new PCK-student</b> ) holding a detailed discussion with a student enables the expression of his/her reasoning ( <b>tacit PK-strategy</b> )
example 3	group 1: Pierre wrote a chemical equation which does not respect the composition of the initial state of the mixture (two acids and two bases), but interprets what happened in the acid solution	individual reflection	1) asked for an explanation 2) corrected the error telling him he should take the predominant species of each solution into account 3) did not ask for the detailed composition of each solution with group 2, as she did with group 1 in episode 1	student's reasoning not anticipated	he forgot to take the relevant species in the initial state of the mixture in the chemical equation	video not watched	it is difficult for a student to take only the majority solute of an acid or base solution into account to predict what could happen in a mixture ( <b>expressed PCK-student</b> ) it is no useful to remind the detailed composition of each acide or base solution, since the students are asked to predict what could happen in a mixture of four solutions ( <b>tacit new PCK-strategy</b> ) holding a detailed discussion with a student enables the expression of his/her reasoning ( <b>tacit PK-strategy</b> )
example 4	group 1: searching reasons for the chemical change (episode 3) and attempting to write a chemical equation (episode 4)	1) individual reflection 2) collective dialogue	group 2: asked for the writing of the chemical equation (episode 2) before the possibility of any chemical change (episode 6)	student's difficulty not anticipated	reflecting on the chemical change before writing a chemical equation confused the students, so I changed the tasks order	video not watched	reflecting on the chemical change before writing a chemical equation confused the students ( <b>expressed new PCK-student</b> ) writing the chemical equation should be done before looking for any chemical change ( <b>expressed new PCK-strategy</b> )
example 5	group 1: expressing the initial reaction quotient (episode 9) then calculating the concentrations ratio (episode 12)	individual reflection	changed the tasks order with group 2	not adressed	I changed the tasks order because the concentrations ratio calculus was a direct consequence of the pH measurement to determine the change direction of the mixture	video not watched	calculating the initial reaction quotient before the concentrations ratio does not enable the students to determine the direction of chemical change ( <b>expressed new PCK-student</b> ) the initial reaction quotient calculus should be made after the concentrations ratio calculus ( <b>expressed new PCK-strategy</b> )

table 2: some examples of reconstructed PCK and PK