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Promoting Awareness about Pedagogical Content Knowledge

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Abstract—The purpose of this research is to evaluate the impact of the feedback gained from targeted self-confrontation on a teacher's knowledge about his own practice. To do so, we opted for a case study within a qualitative approach. Through a sequence of self-confrontations, we employed content representation (CoRe) as a tool to advance a teacher's pedagogical content awareness. We investigated the evolution of content representation during three self-confrontations assisted by CoRe. And we used the outcomes to draw up a CoRe design for each self-confrontation. The topic of teaching was air components and combustion. The results show an important increase of content aspects considered by the teacher during self-confrontation. We concluded that CoRe is an efficient tool that can contribute to elicit teacher's awareness about the significant aspects of content pedagogical knowledge.

Keywords: Reflective practice, pedagogical content knowledge, content representation, combustion, air components

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1. INTRODUCTION

Teachers gain their professional skills in initial studies and must continue to develop their performance through continuous learning and experience. In fact, among their practice, teachers face many challenges related to knowledge transfer. To meet those challenges, they must master both content and pedagogical knowledge related to the subject they are teaching. In this case study, the object of teaching is a module titled "the air". It covers the composition of air, combustion, combustion factors, and products. But observations showed that understanding of combustion from students' perspective is not the same from a scientific perspective. (Boujaoude, 1991; Meheut, 1985; Watson et al., 1997). Students also show many misconceptions related to the physical characteristics of air (Plé, 1997). To reduce the gap between the two perspectives, teachers should have a good understanding of students' difficulties and should use the best strategies to help them acquire scientific knowledge. To achieve that, teachers need to develop professional skills and must be sensitive to students' needs. Research had proven that one of the most important practices that allows teachers to be more conscious about their performance in class is self-confrontation (Jay & Johnson, 2002; Schön, 2017; Stanley, 1998). So how can self-confrontation improve a primary school teacher's professional knowledge about teaching air composition and combustion?

2. Literature review

A multitude of efforts have been made to conceptualize teaching skills and to describe the knowledge developed in the teaching activity (Guerriero & Deligiannidi, 2017; Hiebert et al., 2002; L. Shulman, 1987). One of the main conceptualizations of this knowledge is the PCK (Pedagocial Content Knowledge). Shulman (1986) developed a theoretical framework for modelling teachers' pedagogical content knowledge (PCK) in order to better understand teacher's approaches to teaching particular content. That model focuses on pedagogy and topic knowledge in a way that it influences teachers' practice. It describes the complex aspects of the knowledge that leads science teacher's instructions. (Carlson et al., 2019). It defines different components of PCK: collective (cPCK) which contains professional knowledge shared by a group of specialized teacher, personal (pPCK) which describes personal knowledge held by one teacher, and enactive (ePCK) which included the kind of knowledge that a teacher implements when teaching and when reflecting on his own practice (Carlson et al., 2019, p. 6).

The PCK model provides insight into the reasoning behind the practice, and the planning that leads to teaching a particular topic in a particular way (Julie, 2015). It has been used to improve teachers' professionalization through training or through collaborative research. One of the tools suggested by researchers to describe and promote teachers' different PCK components (cPCK, ePCK, pPCK) is Content Representation (CoRe). (Carpendale & Hume, 2019). In fact, CoRe is an interview instrument that gives researchers access to science teachers' knowledge of the subject. It is also a method to present that information (Loughran et al., 2004). Interview based on CoRe covers the main ideas that a teacher found pertinent to teach a particular topic. CoRe was originally created to assist teachers in reflecting on their understanding of how to teach specific content (Goes & Fernandez, 2016). It (CoRe) is generally designed through workshops that involved groups of teachers. Previous studies had proven the advantages of early career teachers participating in CoRe' s design with specialists (Williams et al., 2012). But this research was based simply on experimental observations without using theoretical proof to justify the PCK's promotion. This is why we suggest using the concept of variation to confirm that effective learning did happen.

The concept of variation is a derivative of the phenomenographic theory introduced in the late 90's (Marton & Booth, 1997). It provides a theoretical foundation to comprehend some of the essential conditions for learning (Lo & Marton, 2011). It is generally used as a guiding principle for pedagogical planning that can be applied to different subjects (Lo & Marton, 2011), such as mathematics (Kullberg et al., 2017), chemistry (Bussey et al., 2013), and others. One of the basic principles of this theory, that it focuses on the object of learning and must lead to a qualitative change regarding this object (knowledge, skills, etc.). This principle presents a theoretical base to explain the use of self-confrontation in the development of teachers' professional skills. "From a Variation Theory perspective, learning is seen as an expansion in awareness, in which students become aware of critical aspects of a disciplinary concept, skill or practice" (Åkerlind, 2015, p. 6). The process of learning implies that the individual must be able to select significant stimuli from irrelevant ones, and reorganize them to attend a new level of knowledge (Juhler, 2016). To put a teacher through a self-confrontation process means to expose him to a large number of stimuli. Learning in this case is the ability to select and interpret the important details related to PCK. In fact, variation theory points out that "Learning is a function of discernment and discernment is a function of variation" (Ling Lo, 2012, p. 29).

This research aims to investigate how the feedback gained from the practice (ePCK) can potentially improve the shape of the teacher's beliefs and attitudes regarding the subject he is teaching (air components and combustion) and the best way to teach it (pPCK). This feedback is obtained through self-confrontations based on CoRe, and PCK promotion is confirmed based on variation theory.

2. METHODS

This research aims to capture the development of teacher's PCK through self-confrontations assisted by CoRe template. This study is, in fact, based on a qualitative approach, a kind of case study. Data were gathered using qualitative research techniques that centered on observations, self-confrontations, and document analysis.

2.1 Research Design

The research's purpose is to measure the evolution of PCK related to teaching air and combustion through targeted self-confrontations. To get an in-depth exploration of the impact of the feedback gained from a teacher's practice on his pPCK, we opted for a case study. We attempted to capture the development of the number of features related to enacted PCK that the teacher considers when he comments and explains his actions. The data we need to collect is the main ideas expressed, which are related to the important aspects of pedagogical content knowledge the teacher perceived.

2.2 Participants

The teacher was chosen on a volunteering basis. He is a primary public-school teacher with five-years of experience. Primary school in Tunisia lasts 6 years. It starts from the age of 6 until 12. Classroom observations took place with 6th grade students (11 up to 12 years old).

2.3 Instrument

To collect data, we used two tools: observations and self-confrontations. We attended three lessons of physics in primary school, and we filmed them. The lessons belong to a module titled "the air". They cover composition of air, combustion, combustion factors, and products. Each lesson lasted between 40 to 60 minutes. The self-confrontations were also registered and analyzed in the following step. Each self-confrontation lasts between 60 to 90 minutes.

2.4 Procedure

After attending and registering three classroom observations, we started a series of self-confrontations. The first self-confrontation consists of two parts. The first part was spontaneous: we asked the teacher to freely comment on his actions. The instruction given to him was very simple. "Try to focus on this content aspects while commenting your practice". The second part was guided using a CoRe template to identify the most important features related to PCK. We asked the teacher to focus on the different aspects cited in the Core interview to explain their practice. The rest of self-confrontations was all assisted from the beginning by CoRe template. The teacher knew in advance the aspects we need him to focus on which are:

1. What you intend the students to learn about this idea?
2. Why is it important for the students to know this?
3. What else you know about this idea (that you do not intend students to know yet)?
4. Difficulties connected with teaching this idea.
5. Knowledge about student thinking which influences teaching about this idea.
6. Other factors that influence your teaching of this idea.
7. Teaching procedures (and particular reasons for using these to engage with this idea)
8. Ways of ascertaining student understanding or confusion about the idea. (Loughran et al., 2004)

2.4 Data Analysis

Data analysis uses descriptive techniques such as data presentation through CoRe design, and conclusion. Transcriptions from all self-confrontations were initially

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analyzed to conclude, through the teacher's reflections and interpretation, the big ideas related to the topic he developed, and the content's aspects he considered and focused on each time. Those main ideas were mapped for each self-confrontation. Then we used CoRe model as a basis to gather, categorize, and present those ideas.

3. RESULTS

We used the data collected to draw up the CoRe design and associated PaP-eRs (Pedagogical and Professional experience Repertoires) of each self-confrontation. The following CoRe matrix corresponds to the analysis of the spontaneous part of the first self-confrontation. The Kea ideas are the object of learning that the teacher reclaims important for students to know.

Table 1. CoRe for "Composition of Air" (Data Gathered from the Spontaneous Self-Confrontation)

Key idea B	**Key idea C**
Students must identify water vapor as air component through the first experiment	When the oxygen is depleted, the candle goes out and the water rises and attend 1/5 of the jar' s volume
	Students should remember that oxygen supports combustion to understand the experiment
	I used mental carte to illustrate different components and join them to their characteristics

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	Key idea A
What you intend the students to learn about this idea?	Through the observation students must give predictions about the drops of the water appearing on the glass
Why is it important for the students to know this?	
What else you know about this idea (that you do not intend students to know yet)?	
Difficulties connected with teaching this idea.	
Knowledge about student thinking which influences teaching about this idea.	Some students thought that the drops of water came from other resources such as exhaling
Other factors that influence your teaching of this idea.	
Teaching procedures (and particular reasons for using these to engage with this idea)	
Ways of ascertaining student understanding or confusion about the idea.	

The first CoRe matrix illustrates that the main ideas were not very developed. The teacher focuses on the learning objects he intends the students to know. He developed 3 main ideas related to the content. But he did not give deep explanation of the content area. In fact, some aspects were totally absent such as the importance for students to know a specific topic or the ways of ascertaining student understanding or confusion about the idea. The following CoRe matrix is designed using the second part of self-confrontation. CoRe was used as a tool to direct the teacher towards the main aspects of PCK. We intended through it to create the possibility of the existence of the most important conditions of learning corresponding to variation theory which are: Concentrating on the object of learning and considering that knowledge is a form of perception (Ling Lo, 2012).

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Table 2. CoRe for " Composition of Air" (Data Gathered from the First Oriented Self-Confrontation)

	Key idea A	**Key idea B**	**Key idea C**
What you intend the students to learn about this idea?	Students should be able identify air composition. And the proportions of the components.	Explore new concepts such as oxygen, carbon dioxide, and nitrogen.	Identify some air components characteristics through experiments
Why is it important for the students to know this?	It is important for students to know about the air they are breathing	Students need to know some principal chemical elements	Proving the existence of an entity through its consequences or characteristics is an important skill
What else you know about this idea (that you do not intend students to know yet)?		Carbon dioxide is related to air pollution.	
Difficulties connected with teaching this idea.	Students think of air as full entity. It is hard to make them see it as a group of elements	Teaching about gas generally make students reconceptualize the concept of matter.	Conducting experiments properly is the major challenge.
Knowledge about student thinking which influences teaching about this idea.		It is hard for student to identify invisible elements they cannot see feel or touch	
Other factors that influence your teaching of this idea.			
Teaching procedures (and particular reasons for using these to engage with this idea)	working in small groups while conducting experiments so everyone can participate.		I followed the guidelines in line with the skills-based approach.
Ways of ascertaining student understanding or confusion about the idea.	Through experiments we will prove some representations wrong.		

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The CoRe matrix above shows an important development of the reflection related to the biggest ideas. In fact, the number of ideas developed did not increase (three each time). But 7 from 8 content dimensions were commented by the teacher to explain each one of the ideas. Through the second and the third self-confrontation, (see appendix: Table 4 and 5) the number of biggest ideas is constant. Generally during each lesson, the teacher has three main objectives he intends students to learn. All the self-confrontations motivated by CoRe contain more details related to the content teaching. The Table below shows the development of ideas related to each aspect of CoRe through the three self-confrontations.

Table 3. Variation of the Number of Ideas Related to CoRe aspects

	Self-confrontation 1 (Part 1)	Self-confrontation 1 (Part 2)	Self-confrontation 2	Self-confrontation 3	Total developed ideas
1	3	3	3	3	12
2	0	3	1	3	7
3	0	1	2	1	4
4	1	3	2	3	9
5	1	1	2	1	5
6	0	0	0	1	1
7	1	2	3	3	9
8	0	1	1	1	3
Total	6	14	14	16	

We used the data above to determine the most features that influence the teacher's reflection through self-confrontation. Results prove that the teacher became more conscious about the different dimensions of learning objects. The number of ideas developed with CoRe assistance is twice the number of ideas without it. In fact, comparing the two parts of self-confrontations based on the same lesson, we noticed that learning objects were more precise and inclusive. "We already studied air characteristics Now students should be able to identify air composition and the proportions of the components.", comparing to the ideas from the spontaneous part which were descriptive "Through the observation students must give predictions about the drops of water appearing on the glass". The aspects that were absent in the spontaneous self-reflection were those related to the interpretative reflection. The teacher did not mention the purpose of learning the topic, or the factors that influence teaching it. He focuses on operational aspects such as learning objects, teaching procedure and difficulties he faced through the teaching process.

Through comparing findings between different self-confrontations, we note that the most important aspects that the teacher considers are learning objects, teaching procedures, and identifying difficulties connected with teaching. In fact, difficulties are one of the aspects that significantly increased using the CoRe assistance. The teacher became more aware about stimuli related to the content. We quote his saying "In fact some of air components are combustion factors such as oxygen others are products such as water vapor or CO_2, this will misguide some students they think that air supports combustion. I think also this what makes students confusing air components, and combustion factors and products." The importance of learning the topic, was one of the aspects the teacher did not develop while the spontaneous self-confrontation but develop significantly in the targeted ones. Based on all these findings we can confirm that CoRe is a useful tool that contributes to elicit the teacher's understanding of his own practice and identifying the important features of the content related to it.

4. DISCUSSION

Previous studies proved the importance of CoRe to increase early-career teachers' awareness of PCK (Hume, 2010). According to Loughran (2004), it is used only in a collaborative approach that joined the efforts of experts and teachers. Carpendale and Hume (2019) proved that a collaborative CoRe design show a significant enhancement of teachers' pPCK and ePCK. The knowledge shared has been enriched through different exchanges. Juhler (2016) proved that using CoRe design, to plan physics lessons, helps enhancing teaching knowledge because it elicits them to think about the ways to approach the content based on how students learn a special topic. Hume and Berry (2013) also used CoRe as a tool to help chemistry student teacher acquire their professional knowledge. Those findings are confirmed by this research. In our case, using CoRe design to stimulate reflection made the teacher more sensitive about students' difficulties and enrich his PCK. Until now different CoRe templates have been designed through action research. It covers especially collective PCK (cPCK).

The contribution of this study is that it uses CoRe not only to investigate the teacher's knowledge about the content but also to improve their personal knowledge. CoRe was used in a self-confrontation assisted by the researcher interviewer. In fact, we investigated the relationship between ePCK used by the teacher to describe his practice and the role of CoRe design to make the teacher consider more features during self-confrontation. This enlargement of the area of their judgment across the content area enriches their pPCK. CoRe as a learning tool helped the early career teacher identifying the important features of the content. It promoted the kind of knowledge engaged during reflecting in a lesson (ePCK).

One of the contributions of our research is that it uses variation theory as a theoretical ground to prove that an effective enhance of PCK did happen. According to variation theory, this enhancement of perceived stimuli which leads to a qualitative change in the teacher's judgement is in fact, an improvement of learning about subject matter knowledge, knowledge of instructional strategies, and knowledge of students' understanding. The use of CoRe to assist self-confrontations led to a significant increase of the number of stimuli related to content and considered by the teacher. Which means according to the variation theory an increase of awareness about the object of learning (PCK in this case). This increase of awareness is defined by the same theory as learning.

5. CONCLUSION

Through this research we draw up a CoRe design related to teaching air components and combustion. We worked with a teacher to help him reflect on the content aspects included in his practice. We hope that we helped the teacher think differently about aspects of his practice and contributed to the development of his personal strategy for professionalization. The findings we presented in this article are coming from a case study, so they cannot be generalized immediately. But they are important because they may be a foundation to define another contribution of CoRe design for teacher's professional development. We used the CoRe design to increase the number of considered stimuli implanted through ePCK to enhance the pPCK. But we

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do not if the teacher will mobilize the same knowledge in the future. So as a perspective we can investigate the impact of core design in a long-time process of self-training.

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APPENDIX

Table 1 CoRe for "combustion" (data gathered from the second self-confrontation)

	Key idea A	Key idea B	Key idea C
What you intend the students to learn about this idea?	Student will discover the fire triangle.	Identify the sources of heat.	Some materials burn more easily than others
Why is it important for the students to know this?	If one of the three factors is missing, we cannot start a fire		
What else you know about this idea (that you do not intend students to know yet)?	There is two types of combustion: complete and incomplete.	Heat is also product of combustion	
Difficulties connected with teaching this idea.	Students learnt that air supports combustion, which is not precise. Only oxygen support combustion		It is dangerous to deal with highly flammable materials. We cannot perform all experiments
Knowledge about student thinking which influences teaching about this idea.	It is important to know that oxygen supports combustion not air	Confusion between heat and fire	
Other factors that influence your teaching of this idea.			
Teaching procedures (and particular reasons for using these to engage with this idea)	We started from the hypothesis suggested to answer the question: Why we cannot light the coal.	Working through concrete example such as candle burning	I used digital presentation to show some experiment that we were not able to perform in class
Ways of ascertaining student understanding or confusion about the idea.	Students should identify the fire triangle through concrete situation such as a car engine, candle, etc.		

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Table 2 CoRe for "combustion factors and product" (data gathered from the third self-confrontation)

	Key idea A	Key idea B	Key idea C
What you intend the students to learn about this idea?	The burned material changes.	Water vapor is a combustion product.	Carbon dioxide results from combustion it turns lime water milky
Why is it important for the students to know this?	Understanding the process of burning is important in chemistry	To understand the combustion reaction later	Carbon dioxide is a dangerous gas to health and to the environment
What else you know about this idea (that you do not intend students to know yet)?	Burned materials do not behave the same		
Difficulties connected with teaching this idea.	Difficulties related to materials transformation	Students already know water vapor exist in air, so they do not necessarily relate it to the burning process	Some students do not know about water lame effects and are not capable to relate its impact to the presence of CO_2
Knowledge about student thinking which influences teaching about this idea.		Confusion about air components and combustions products	
Other factors that influence your teaching of this idea.	It is important to know that oxygen supports combustion not air.		
Teaching procedures (and particular reasons for using these to engage with this idea)	Observe the impact of combustion on candle, paper, etc.	Experiments to illustrate the water drops on the glass	Experiment to demonstrate carbon dioxide on lame water
Ways of ascertaining student understanding or confusion about the idea.	Drawing a mental carte that illustrate factors and products		

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