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Science teachers' teaching actions in their classrooms: Pedagogical content knowledge and skills

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Abstract

This study offers empirical evidence of science teachers' teaching actions in their classrooms comprising a combination of knowledge components and teaching skills (PCK&S). Pedagogical Content Knowledge (PCK) is a combination of knowledge components for teaching (Mavhunga, 2020; Tufail et al., 2020) and skills are teachers' intellectual actions for teaching. The Consensus models of PCK (Carlson & Daehler, 2019; Gess-Newsome, 2015) have highlighted the importance of teachers' PCK and skills in teaching practices, therefore, the first PCK consensus model (Gess-Newsome, 2015) was adopted as the conceptual framework for this study. This case study examined two experienced science teachers during their teaching of a chemistry unit to Year 10 students in New Zealand classrooms. The data were collected using a questionnaire, document analysis, lesson follow-up interviews, and classroom observations including video recordings. All the gathered data were transcribed and imported into NVivo for coding. The literature-derived analytical framework was constructed for analysis. The finding shows that teachers' teaching practices reflected varieties of combinations of two or more knowledge components through skills (PCK&S). The combinations of knowledge are tacit while skills are more explicit during practice. The findings seek to contribute to the understanding of how the components of PCK and skills may be related and visualized through the act of teaching.

Keywords: PCK, Teaching skills, Chemistry teaching, Case study

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Introduction

Good teaching practice is associated with teachers' pedagogical content knowledge (PCK) (de Sá Ibraim & Justi, 2022) and impacts students' learning progress (Park & Chen, 2012). In more than a quarter century of PCK research, there are different views regarding PCK (Neumann et al., 2019). Teachers' PCK is a result of combinations of knowledge components for particular teaching. The recent development in PCK (Carlson & Daehler, 2019; Gess-Newsome, 2015) also discussed teachers' actions within the PCK notion. The first consensus model of PCK (Gess-Newsome, 2015) considered teachers' actions in the classroom based on teachers' PCK (PCK&S). Subsequently, the refined consensus model discusses this aspect under enacted PCK (Carlson & Daehler, 2019). According to our knowledge, now a decade has gone on theoretical propagation of this concept (i.e. PCK&S) but no or very little empirical research evidence support how teachers' PCK and their skills together are evident in science teaching. This study investigated PCK that expresses through teachers' teaching skills in their chemistry teaching. The remaining section presents a literature review of the study.

Literature Review

Research on teaching and learning changed our understanding of teaching practice. Teaching had been considered just transferring content (Warren, 1985). Whereas, researches reported teaching as a complex process instead of a simple activity where teachers adjust their strategies to enhance learning in the classroom (Barnett & Hodson, 2001) and the credit of this complexity indicates the development of teachers' PCK (Williams et al., 2012). PCK has a tacit nature which makes it very challenging to understand fully (Park & Oliver, 2008) as PCK is a teachers' constructed knowledge combination according to a situation. On the other hand, teachers' expression of knowledge and representations can make their PCK visible in a classroom (Carlson & Daehler, 2019). This disagreement was raised because most PCK studies have perceived PCK as knowledge construction rather than PCK as an act of teaching (Tufail et al., 2019). There is an interesting perception of PCK: it is static because it refers to knowledge about teaching and it is a dynamic or skill when it is active in the practice (Nilsson & Vikström, 2015). The finding of this study can enlighten the dynamic aspect of PCK when it interacts with skills in classroom practice. It can also illuminate theoretical concepts of PCK&S in real classroom situations. This combination would help to understand experienced teachers' PCK&S to tackle their teaching situations.

The present theoretical consensus models (Carlson & Daehler, 2019; Gess-Newsome, 2015) have stressed the classroom practices aspect to know "teachers' PCK" in operation. The first consensus model (Gess-Newsome, 2015) delineates PCK into teachers' personal PCK, and teachers' PCK and Skills (PCK&S). In this model, it is conceptualized as embracing both teachers' knowledge (i.e., what the teacher knows) and knowing (i.e., decisions) (Chan & Hume, 2019). PCK&S was taken in a broad sense as "all acts of teaching" in the process of teaching, concisely, "we recognized that what a teacher does in the classroom is also based on their PCK" (p. 36). As a PCK investigator, some questions occurred in my mind (the first author). For instance, in a classroom what actions are founded on teachers' teaching skills? OR are all teaching actions in their classroom based on their skills? It is established in the literature that the actions of teachers are not built on their teaching skills. By way of example, in 1960, competency-based teacher preparation was considered worthiness, then, teachers' competencies started to relate to the effectiveness of teaching, after that, the impression of competency in teaching was intermixed with the idea of skills in teaching practice (Kerry & Wilding, 2004). The competencies are more related to physical actions while skills are more specific to intellectual processes. A teacher's teaching consists of competencies and skills, hence, there is a very blurriness boundary between them. In our view, teaching skills embrace teachers' estimation of rationalizing their actions in teaching that might influence students' progress. Therefore, it is difficult to visualize during practice. The skills can be examined in teachers' set lessons' objectives, generation of questions, adoption of suitable teaching methods, selection of classroom context as a teaching aid, in the decision-making process, class evaluation and provided feedback, etc. Actions based on teaching skills (PCK&S) are considered for this research as those actions which are related to teachers' intellectual processes that involve constructing science concepts for teaching according to a particular context (i.e., students) and particular situation. This study can light up the understanding of the interaction of PCK and skills for teaching.

The notion of PCK&S was theoretically established by PCK experts in the PCK summits. This recent development in the area of PCK has renewed interest in *what* teachers know, and *how* teachers use PCK and skills in their teaching. Trying to fill this gap, this study examined teachers' PCK with their skills in their chemistry teaching.

Research Question

RQ: How experienced science teachers use their PCK&S in their chemistry classroom practice?

The upcoming section discusses the research design and analysis procedure of the study.

Research Design

A qualitative research approach is suitable to get a detailed description of classroom practice (Merriam, 2009). A multiple case study was adopted for this research as Cohen, Manion, and Morrison, (2018) recommended a case study for such studies. Moreover, some previous researchers also used a case study for investigating PCK in classrooms (e.g., Aydin, Friedrichsen, Boz, & Hanuscin, 2014; Barendsen & Henze, 2019; Carpendale, 2018; de Sá Ibraim & Justi, 2022). Two experienced (more than 20 years) science teachers were examined during their teaching practices in New Zealand classrooms. The teachers were observed during their teaching of a complete chemistry topic to their junior secondary school students (Year 10, 14-year-olds, 30 boys). The students were not part of the data because the research focused on investigating teachers' knowledge components and skills. PCK belongs to teachers' constructed knowledge for teaching, therefore, the focus of data was only teaching of teachers ; Moreover students were not considered the main source of the data.

Data were gathered by classroom observations and post-lesson interviews. Classroom observations include notes and video recordings for examining teachers' expressed PCK, followed by lesson follow-up interviews, and a post-topic interview with each teacher. Only one camera was used to capture the data that focused on the teacher only. Those video recordings helped to slow down the videos, pause them, and divide them into teaching episodes. The various aspects of this research (i.e. data triangulation, cross verification of the data, rich description, and multiple cases) contribute to its credibility, transferability, and trustworthiness (Creswell, 2013; Yin, 2009).

The gathered data were organized systematically from an analytical standpoint. In the first phase, the classroom observation videos and interviews were typed up. These transcribed documents were shared with participants for its validation. In the second phase, the data was analyzed by using NVivo. For analysis, the analytical framework was constructed. The deductive and inductive approaches were used for coding. In the third phase, gained codes were congregated and presented into findings. Figure 1 represents the flowchart of these three phases.

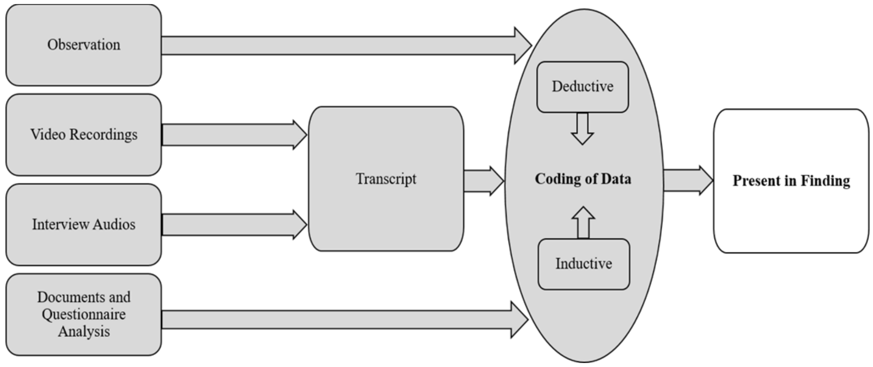

Figure 1: Flowchart for Analysis

Findings and Discussion

The analysis indicated that the two teachers typically appeared to be using a combination of knowledge components (two or more) in their teaching at any one time. It also examined that sometimes these combinations appeared with teaching skills. We illustrate here fragments of data when each teacher appeared with their PCK and skills at a single teaching moment.

Griffin (participant's pseudonym) was a non-specialist chemistry teacher. The data was collected when he taught ionic chemistry to Year 10 students. In lesson 2, he was explaining the number of electrons in an oxygen atom. He noticed some students were talking with each other then he asked questions to those students (Lesson-2). He appeared to combine his knowledge of students and pedagogical knowledge in decision-making when he switched teaching approaches, which helped him to cater to his students' needs. As he explained:

"These persons find it hard to concentrate for the whole period so when they start to get chatty or when they start to lose concentration, at that point if I do not give them something to do when they are not going to learn anyway. So, when they start to lose concentration, then it's better to stop and say, Okay we will do something different". (Griffin, Interview after lesson 2)

He appeared to be using his knowledge of students to describe his students' behaviour about retaining sustained concentration and identified his observations in the classroom as students being 'chatty' or that they 'lose concentration. Drawing on this knowledge of how the students behave when they lose concentration in chemistry learning, he changed the approach to better support students' ongoing engagement to enhance student outcomes. His belief that "it's better to stop" indicates an evaluation of the class' behaviour by using "professional vision" (analysis of the overall classroom activities) (Goodwin, 1994, p.606) and draws on both knowledge components in the combination (i.e. knowledge of students and pedagogical knowledge). The monitoring of class behaviour as a particular action related to teaching is referred to as a skill by Rosenshine (1976). Griffin's knowledge combination afforded this action in the class that indicates his PCK&S. Similarly, when describing his actions in class, he explained:

"They are all (students in the class) so different but I think it is really important that I try to engage as many different boys as possible, so I try to look around the room and I usually ask a question to the boy who has lost focus, but also I try to shift around so they are all thinking about the question". (Interview after the first lesson)

It illustrates his combination of knowledge of students "they are all so different", pedagogical knowledge "I think it is really important … to engage…", and teaching act/skill "I try to shift around so they are all thinking about the question". This act of teaching included the use of a teaching technique, "ask a question to the boy who has lost focus". These intellectual actions depict his teaching skill which has been discussed as a major teaching skill by Zahorik (1986) and keeping students engaged in the learning process by asking questions is a demonstration of mastery of this skill.

He mentioned that summative assessment informed him about the achievement of his own set learning objectives "Hopefully, with questioning, daily. But when they'll do the exam then I'll have a good idea" (Griffin, Interview after lesson 7). It seemed to me, that's why he used ready-made questions from a textbook in the last topic lesson, he assessed the students' topic learning for the final examination. In the topic's last lesson, he opened the book, recalled what they had learned in previous lessons, asked questions, assisted students, and provided reinforcement where he felt it was needed. Asking narrow questions and immediate reinforcement are teacher skills (Rosenshine, 1976), in this case, these skills are a projection of a combination of assessment, pedagogical, and curricular knowledge.

Paul (pseudonym) was a specialist chemistry teacher, who was teaching acid/base chemistry to his class. He described this class as low ability and indicated that he felt repetition was important for them. He appeared to use a combination of pedagogical and content knowledge to create connections between previous lessons and subsequent lessons for his students. After completing a lesson on obtaining common salt by acid-base reaction through the evaporation method (Lesson-7), in the follow-up interview he discussed his planning for the next lesson "Next lesson I'm going to pick up on what happened yesterday. So yesterday we started looking at two acids, one was hydrochloric acid and the other was sulphuric acid. I want to develop nitric acid [concept]" (Paul, interview after lesson 7). This statement shows Paul making a link between lessons in the school's topic planning [the school planning document for this topic showed SLOs and topic content]. Subsequently, Paul began lesson 8 by saying, "Open your [note] books, to what we did on Wednesday in the last period". [He was checking student's notebook]. "We did two equations, hydrochloric acid, and sodium hydroxide". [He repeats the equations by using the whiteboard.] (Classroom observation, lesson 8). These teaching episodes represent a constructive approach as recommended in "*The New Zealand Curriculum"* (Ministry of Education, 2015). Baviskar, Hartle, and Tiffany (2009) professed that the accumulation of learners' prerequisite knowledge is the first step of constructive teaching. After checking the previous classwork and response as reinforcement and more explanation about what part of acid is more reactive, immediate reinforcement skill was integrated with his knowledge combination according to that situation. He assessed students' work, the reflection of the previous lesson was assessment skills (Zahorik, 1986), and immediate reinforcement skills were combined with his content knowledge, and pedagogical knowledge. He developed his PCK according to the situation. The idea of knowledge combinations within PCK is well connected with other researchers who discussed teachers' construction of PCK according to contextual-specific and situation-specific (e.g. Abell, 2008; Kind, 2009; van Driel & Berry, 2012). It is a unique study from other studies because it examines a connection among combinations of knowledge components with teaching skills in their classrooms.

Griffin in his lesson 6, arranged experimental apparatus for demonstration. That organized activity was based on last week's taught lesson [identification of cations]. He started with some questions to diagnose students' learning. It seemed that when he got little satisfaction about basic learning among students then he explained more about today's activity; "you [students] write the chemical names and then you will mix these chemicals and see what will happen? After that, I'll help you to figure it out. We will discuss the balance of the chemical equation later this week" (Lesson 6). Then he demonstrated the activity,

"We put clear liquid [cation solution] in a test tube of approximately 1ml. You see the written instructions [on the instruction card]. I put in a couple of drops of sodium hydroxide relatively dilute and shake it, and the colour changed. [He wrote practical instructions on the whiteboard. He reads instructions with a brief explanation.] You will need these chemicals, written instructions, a test tube rack, and a couple of test tubes [for this practical]". (Lesson 6)

This episode indicates the combination of his pedagogical knowledge, content knowledge, and classroom management skills to lead the practical activity in the science room. In this teaching episode, he started with content knowledge and then turned into feedback to assess students' knowledge, use the context, demonstrate, remind the health and safety policy in the lab, guide the students throughout the activity and then evaluate the result of that activity shows his combination of skills with PCK. He used different proportions of his assessment, contextual knowledge, curricular knowledge, and content knowledge for this particular teaching. This finding echoed the findings of Liepertz and Borowski (2018), they found in the quantitative part of their research project: teachers' personal PCK is actually teachers' use of knowledge from teacher professional knowledge base (TPKB) and topic-specific professional knowledge (TSPK) in teaching by using skills, PCK&S. The discussed knowledge combinations portrait the knowledge components combined according to content and context. This finding put light on the theorized idea proposed by de Sá Ibraim and Justi (2021) about the development of PCK, a teacher's knowledge combination for particular content and audience.

Paul stopped the experimental activity for the whole class due to an apparatus breaking by a student group. In lesson 4, he started a practical activity (separate salt and water through evaporation). At the start, a group of students broke an evaporating dish. He stopped the activity and said,

If it happens again, then this experiment is out, and I will just assign them bookwork. They'll be copying from the book, nothing else until they learn they need to settle down and follow the teacher's instructions… I am not going to put the experiment off again and again. (Interview after lesson 4).

It indicates that the classroom context act filters the teacher's topic planning 'I am not going to put it off again and again. The teacher needed to manage the situation by management skills and motivating the students for learning, but the teacher was ready to surrender, and changed the strategy 'copy from the book'. The combination of knowledge components with skill can help to continue teaching practice. Griffin managed the practical activity by using a combination of knowledge and management skills while Paul did not carry out the activity due to lack of management skills. A positive relationship is identified between teachers' management skills and class disciplinary behaviour in the classroom (Kayıkçı, 2009). The data shows that teachers' skills based on PCK helped them to carry out teaching practices effectively to enhance students' chemistry learning. The next section subscribes to the conclusion of the study and recommendations for potential applications.

Conclusion and Recommendations

Our first assertion here, teachers' acts (PCK&S) are more explicit than knowledge combinations (PCK). Teachers' acts were observed in their classrooms while combinations come at the front in their follow-up interviews on asking about their acts. In the discussed data, knowledge components of PCK were combined with skills in particular episodes. This study highlighted teachers' skills combined with their PCK that were observed in their classrooms. This finding enlightens the finding of de Sá Ibraim and Justi, (2022), these researchers found PCK constituents integrated with teachers' argumentation skills. These combinations of knowledge components in specific situations for specific students are representing their situation-specific PCK and their specific act representing PCK&S. Park and Chen (2012) mapped PCK in their study that showed an interlink connection present among knowledge components but not all components involved all time. The study of Aydin and Boz, (2013) reconfirmed that all knowledge did not present in the teaching of two chemistry teachers. These researchers did not underpin teachers' skills in the classrooms while our findings seek to contribute to developing how the components of PCK may be related and visualized through the actions of teaching (PCK&S) in teachers' teaching. The following figure showcases the interaction of knowledge components and teaching skills for PCK&S.

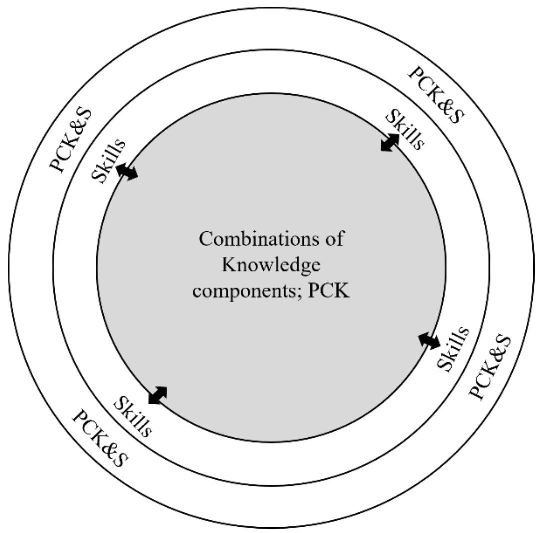

Figure 2: PCK&S in classroom teaching

Herein, the internal part of the figure represents teachers' knowledge combinations for teaching. It was tacit in the classroom practice and appeared in the follow-up interviews, therefore, it's presented in the center of working. These combinations of knowledge informed specific skills (e.g., assessment skills) for action in the classroom practice. The two-headed small arrow between skills and PCK represents those specific skills that need to express particular knowledge combinations in teaching, similarly, skills need to choose the right knowledge in combinations. The outer rim here represents teachers' PCK&S as a resultant of inner circles, and it is more visible in the classroom.

The second assertion is teachers' skills are based on their combined knowledge; knowledge in the combination helped teachers to handle the situation effectively that appears in the form of their skills. The combination of knowledge components is topic-specific (e.g., Park & Chen, 2012), whereas, we found that teachers' particular skills in the classroom (e.g., immediate reinforcement, decision, acts of assessment) are based on this topic-specific combination of PCK components. Literature shows interconnections between these knowledge components (Barendsen & Henze, 2019) and teachers combine these knowledge components in a variety of ways during practice (Beyer & Davis, 2012). The key contribution of this study is to provide insight into how teacher skills combine with their PCK for a particular action in teaching (PCK&S). The findings could help teachers, particularly beginning teachers to understand how different knowledge components within PCK may be enacted in the classroom. This study provides a case of experienced science teachers in their classroom practice that offers an opportunity for student science teachers for understanding the teaching in a real situation as McDowall and Hipkins (2019) highlighted that by observing experienced teachers, teachers can develop their own PCK.

This study was limited to the single chemistry topic teaching which cannot represent the whole chemistry teaching of that teacher. Also, the data from teachers' one topic cannot show a complete sense of the PCK that they developed in their teaching career. Future research needs to underpin one teacher's PCK in different topics of science teaching with different classes, to investigate changes in PCK&S by changing content and context.

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