https://doi.org/10.36315/2025v1end091
Education and New Developments 2025

THE ORIGIN AND ACQUISITION OF PCK FOR TEACHING SCIENCE: A CASE OF PRE-SERVICE TEACHERS' PLANNING TO TEACH UNFORESEEN TOPICS IN LIFE AND NATURAL SCIENCES

Tholani Tshuma
Department of Maths, Science and Technology Education, Walter Sisulu University (South Africa)

Abstract

This study investigated the origin and acquisition of student teachers' PCK for teaching natural and Life sciences. Shulman's PCK, pedagogical action and reasoning; and the theory about students' preferred learning styles were used as theoretical lenses that guided this inquiry. The students were taught how to apply the knowledge bases for teaching (as propounded by Shulman, 1986) during the teaching of Natural and Life Sciences. Five topics from each subject were used to model teaching based on the knowledge bases and the students were expected to extrapolate that learning across how to teach other topics in the South African CAPS syllabus document. The students were then given random other topics not taught how to teach for them to design a lesson plan that entailed the application of the different knowledge bases for teaching. The focus of this research approach was to find out what informs the pedagogical reasoning of the student teachers when planning to teach a topic not prior taught about how to teach it. Collected data included student teachers' lesson plans on topics randomly assigned to them and interview transcripts from three students selected for in-depth investigation. This study established and added a new dimension that whilst the general understanding is that the PCK for teaching science is acquired mainly through formal teacher training and during in-service practising after training, the impactful PCK for teaching science is also acquired and conceptualised during years of students' being taught and learning of science subject content (coined entrenched or engrained PCK for teaching science). The findings from this inquiry help to inform the recommendations that educators of science subject content at any level ought to model good science teaching as this is a powerful way of entrenching PCK for science teaching; so that the vicious cycle of poor teaching is broken and not passed from teacher to student, and then from the 'new teacher who was a student' to 'new student'.

Keywords: *Pedagogical content knowledge, entrenched PCK, teaching, subject matter knowledge, science teaching.*

---

1. Introduction and background

This study investigated the origin and acquisition of pre-service teachers' PCK for teaching Life sciences (Biology). Whilst the teachers' PCK for teaching science has been hailed as being instilled through processes such as teacher training, continued in-service teaching practice after graduation (Shulman, 1986), attendance of teaching workshops, and engagement in communities of teaching practice (Mavhunga & Rollnick, 2017), other possible avenues that could be crucial in the acquisition of ones' PCK for teaching science has largely not been fully interrogated. As a teacher educator, I noted dilemmatic instances in practice. Whilst the different cohorts of pre-service teachers I taught year in and year out were taught about the educational teaching and learning theory courses, there was very little evidence that they applied such educational theories in their teaching practice. Thus, in my quest to investigate this phenomenon, two research questions guided this inquiry:

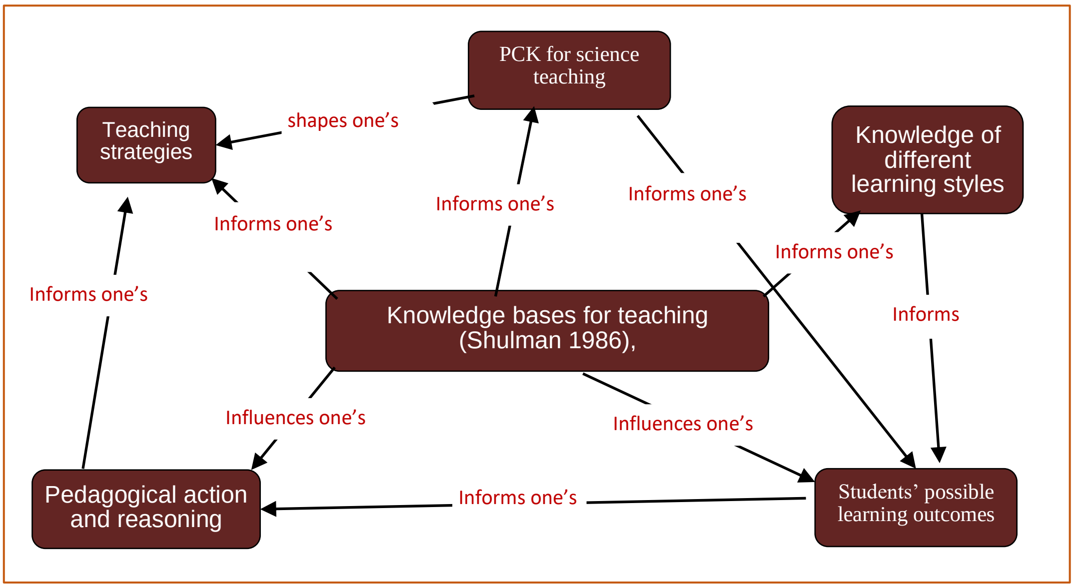
a) What informs the pedagogical reasoning of the student teachers when planning to teach a given random topic not prior taught about how to teach?

b) How do pre-service teachers apply taught educational theories to teacher science topics randomly assigned to them?

2. Bodies of literature reviewed and the conceptual framework

Ideas by Shulman (1986) about PCK and pedagogical action and reasoning (Shulman, 1987); and the theory about students' preferred learning styles (Taylor & Hamdy, 2013) were used as theoretical lenses that guided this inquiry. The relationships between the constructs relevant in this study is provided in a single matrix that constituted the conceptual framework for this inquiry.

Figure 1. The conceptual framework used in this study.



In this investigation, I reviewed pedagogical content knowledge model (PCK) by Shulman (1986) so that I was aware of the types of knowledge bases that teachers should have to teach effectively. Shulman (1986) points out that expert teachers should have *subject matter knowledge, pedagogical content knowledge*, and *curricular knowledge* for them to teach effectively. Each of these is briefly discussed below in the context of how they were used and applied in this inquiry.

According to Shulman (1986, p. 9), subject matter knowledge, is *'.... the amount and organization of knowledge per se in the mind of the teacher*'. The subject matter knowledge which teachers have determines the quality of learning their students experience (Berry *et al*., 2008) because as pointed out by Annetta and Dodger (2006, p. 44), '… *the most important component of PCK is science content knowledge'*. In addition to content knowledge, an expert teacher also ought to have knowledge of the curriculum. Curricular knowledge is about three issues. Firstly, it is about the teacher's knowledge of curricular resources for use when teaching a specific topic for maximum student learning. Secondly, it is about the knowledge of the depth and breadth of the subject matter content which ought to be taught to students in a specific level/grade. Lastly, curricular knowledge also entails knowledge of what was taught in the lower levels or grades and linked ideas that would be taught in the upper grades in that specific discipline/subject (Shulman, 1986). In this investigation, my quest was to find out the student teachers' application of curriculum knowledge in their planning to teacher a given topic.

Shulman (1987, p. 8) defines 'pedagogical content knowledge' as a construct that: ... *identifies the bodies of knowledge for teaching. It represents the blending of context and pedagogy into an understanding of how particular topics, problems, or issues are organized, represented, and adapted to the diverse interests and abilities of students, and presented for instruction.* In this inquiry, I considered PCK to be about knowledge of how student teachers were going to plan how to teach given topics because, according to Shulman, for teachers to teach a particular topic effectively, they ought to have appropriate pedagogical strategies, or what he terms: *"... the most useful forms of representation of those ideas, the most powerful analogy, illustrations, examples, explanations, and demonstrations – in other words, the ways of representing and formulating the subject that make it comprehensible to others"* (Shulman, 1986, p. 9). My quest was to find out if the students could represent content in different ways applicable and relevant for enhanced learner understanding.

In this investigation, because my quest was to find out what informs the students' pedagogical reasoning their pedagogical reason, I also reviewed the idea of pedagogical action and reason.

2.1. The idea of pedagogical action and reasoning

Pedagogical reasoning entails teachers' use of their professional knowledge to decide on how to teach given content (Shulman, 1987). Shulman's (1987) model of pedagogical reasoning and actions involves a cycle of six actions that emerged relevant in this inquiry. The cycle includes the student teachers' understanding (*comprehension)* of major concepts of the topic to be taught. In terms of planning for teaching, this is about representing the content for teaching for enhanced particular cohort of students' understanding (*transformation*). Then the teaching of the given content (*instruction*) follows. After teaching, evaluating the effectiveness of one's teaching and that of students' learning (*evaluation*) occurs. Evaluation is then followed by reflections on the strengths and weaknesses of one's teaching in the light of the students' learning outcomes (*reflection*). Finally, getting a different understanding of pedagogical ideas from feedback from others [*new comprehensions*] completes the cycle (Shulman, 1987; Bishop & Denley, 2007).

2.2. Diversity issues in students that inform teacher planning

When planning to teach, it is crucial for teachers to bear in mind that there is diversity in terms of the students' preferred learning styles (Cassidy, 2010). Some students learn better through seeing what is being taught (visual students), others through hearing what is being taught (auditory musical students), others when content is represented as words, either as speech or writing or both (linguistic students), and yet others through manipulating the environment (Kinaesthetic students). Some students also learn better when engaging in logical reasoning (logical students), others when interacting with significant others (interpersonal students), and lastly, some learn better on their own as individuals (solitary students) (Taylor & Hamdy, 2013).

3. Methodology

A quasi-controlled experiment involving 40 pre-service teachers was used in a bid to answer the research questions for this inquiry. The experimental group (n=20) was exposed to interactive lectures, where they raised questions in class discussions on three teaching and learning educational theories: PCK, Learning styles, Constructivism of knowledge. The lecture sessions involved PCK knowledge bases for teaching [curricular knowledge, pedagogical content knowledge, and subject matter knowledge] (Shulman, 1986). This group was also taught about the issue of what informs the teacher's action and reasoning during teaching, i.e. ideas about Shulman's (1987) pedagogical action and reasoning. Furthermore, these students were also taught about the idea of student diversity in relation to how they prefer to learn. In addition to this, the experimental group was also exposed to lecture discussions on the idea of social constructivism of knowledge as propounded by Vygotsky (1978).

In a bid to eliminate issues of having skills of drafting a lesson plan affecting the outcome of preservice teachers' planning, both the control (n=20) and the experimental group (n=20) were exposed on how to design a lesson through critiquing a typically given good and bad lesson plan. The experimental group were then also given opportunities for peer teaching involving practices on how to apply each of the three educational theories learnt when teaching specific Life and Natural Sciences topics. The peer teaching sessions also involved modelling 'good' teaching that involved the lecturer teaching the student teachers selected content in ways that illustrated how the theories of teaching and learning could be applied in a typical classroom. This modelling of 'good' teaching in the context of educational theories was followed by critical class discussions on the strengths and weaknesses of how the modelling was done by the lecturer.

Some pertinent teaching strategies emerged from modelling and peer teaching discussions e.g. the use and importance of group experiments involving making simple mixtures from sand and water, making simple compounds such as iron sulphide from heating a mixture of iron fillings and sulphur and breaking water into oxygen and hydrogen for kinaesthetic students; group discussions on evolutionary trends in the homo species for verbal and inter-personal students; giving homework and individual classwork on concepts taught for solitary students. In addition to this the issue of taking the students as active participants in their learning to pave way for constructivism of knowledge was key part of the conclusive discussions because students are not empty containers into which knowledge can be poured. The student teachers were then expected to transfer and extrapolate that learning about how to teach involving incorporation taught theories across their teaching of other topics in the Life and Natural Sciences syllabus.

The experimental and control groups were then randomly assigned different topics from the syllabus for them to prepare a lesson plan. Forty topics where randomly assigned letters of the alphabet and each student had to use the second letter of the alphabet in his/her surname to pick a topic next to the letter. The rationale for this was to randomly allocate the topics across the amongst the student teachers. The topics assigned to the control and the experimental group were random topics which were not discussed on how to teach before the designing of the lesson plan task. The focus was for the student teachers to come up with a lesson plan that could enhance student learning. Some student teachers who shared the same letters in their surnames had similar topics to plan for. The collected data included student teachers' lesson plans on topics randomly assigned to them, notes on focus group interviews and six interview transcripts from six students (3 from the control group and 3 from the experimental group) who were randomly selected for in-depth interviews. The lesson plans and interview transcripts from the control and the experimental groups were then analysed for patterns that could have been similar or different though the process of content analysis. The process of document analysis involved coding from a deductive (based on ideas available in the current research literature) to an inductive approach (themes that emerged from the data).

4. Results and discussions

Because the student teachers were using the second letter of the alphabet in their surnames to pick topics for planning, some topics that were planned for teaching by respondents from both the control and the experimental group were the same. Table 1 below shows coded sections of the lesson plans on topics by both the control and the experimental groups. The respondents were given pseudonyms and numbers from 1 to 20 for both the control and experimental groups e.g. C8 denotes student number 8 from the control group and E4 represent student number 4 from the experimental group (see Table 1 below).

Table 1. The main teacher/student activity components of the lesson plans by student teachers.

Topic	Control Group	Experimental group
Diffusion	**C4**: *Teacher explains what diffusion all is about while students write notes* [**Teacher centred approach**]	**E12**: *Teacher use textbook notes to explain the process of diffusion* [**Teacher dominated activity**]
Osmosis	**C7**: *Teacher tells the students that osmosis is the movement of water* [**Teacher as the think tank**]	**E2**: *Teacher write notes for students on what osmosis is all about* [**Teacher centred approach**]
Water transport	**C12**: *Teacher asks students to copy notes on the topic of water transport and then explains them in class* [**Overreliance on textbook/ Teacher as think tank**]	**E10**: Teacher tells the students what water transport all is about while they copy notes [**Teacher centred approach/ Teacher as think tank**]
Animal cells Plant cells	**C19**: *Teacher ask students to label diagrams of plant and cells using textbook* [**Overreliance on textbook]**	**E6**: *Teacher explains that cells are made of different parts using a textbook* [**Overreliance on textbook/ Teacher as think tank**]
Genetic defects in human	**C15**: *Teacher explains the dangers of genetic conditions* [**Teacher centred approach**]	**E11**: *Teacher* read a textbook on the topic of genetic disease for the students and explain the main ideas [**Overreliance on textbook/ Teacher as think tank**]
Food Digestion	**C17**: *Teacher tells the students that digestion is the breaking down of food* [**Teacher as the think tank**]	**E1**: *Teacher write notes for students on what food digestion is all about* [**Teacher centred approach**]

Table 1 shows no distinct differences in the pedagogical reasoning patterns of the student teachers from the control and the experimental group when planning to teach unforeseen topics. This is because the thematic coding of the components of the lesson plans of both the student teachers from the control and the experimental group underscores the power dynamics revolving around the teacher during teaching and learning. The teacher and the textbook are emerging as the only sources of knowledge and the centre of student activity. For instance, **C15**: *Teacher explains the dangers of genetic conditions;* **E6**: *Teacher explains that cells are made of different parts using a textbook*

This teacher centred and textbook oriented approach is rooted in the basic premise that students are empty containers into which knowledge can be poured from two sources, the textbook and the teacher. Such pedagogical reasoning is problematic because it is rooted in the behaviourist theory of viewing students as empty containers (Kroll, 2004). This is an inaccurate assumption because students come to class with prior ideas relevant to learning new topics (Shulman, 1986).

The experimental and control group planned the same way as there was no evidence of application of the taught educational theories by the experimental group. For instance, in the case of student teachers who had topics where simple experiments could have been done to cater to the kinaesthetic students (e.g. digestion of starch using amylase experiment), the students only included e.g. a section in the lesson plan that says that the teacher will explain to the students how food is digested. Notably, some pertinent teaching strategies were amiss in both groups e.g. the use of group experiments involving simple diffusion of molecules, osmosis and use of potometer for kinaesthetic students; group discussions on evapo-transpiration for verbal and inter-personal students; giving individual classwork on concepts taught for solitary students. Thus, the planning by both student teacher groups excludes opportunities for constructivist understanding of the content being taught as propounded by scholars such as Kroll (2004).

In a bid to get a deeper understanding behind what informed the student teacher's pedagogical reasoning, in-depth interviews were carried out. In-depth and focus group interviews revealed that the students (both the control and experimental group) subconsciously followed how they were taught when then they were students to inform their pedagogical reason during their planning. This was despite having been recently taught relevant teaching and learning theories and how to apply them during classroom practice for the experimental group. Issues of the students quoting how they were taught then when they were students seemingly had an impact on how they planned, both from the control and the experimental group, e.g.:

C5: *What I know is that when teaching, as a teaching my primary duty is to explain everything to my students.*

E2: *My planning was stemming from my best teacher, I still remember how he taught us and that is why I passed his subject very well*

When **C5** was probed to explain what his phrase: '… *my primary duty is to explain everything to my students'* in relation on whether this included doing experiments and group discussions, his response, '… *this includes everything that is the students' textbook that I need to teach my students'* is indicative of the deep-rooted grasp of the teacher centred-approach as a primary media for content representation and delivery to students by this student teacher, which stemmed from how he was taught science when then a student. This is a point of departure from what other scholars such as Mavhunga and Rollnick (2017) found, e.g. that the teachers' PCK stem mainly from teacher training, attending workshops and engaging in communities of practice.

5. Conclusions and recommendations

This study established and adds a dimension that whilst the general understanding is that the PCK for teaching science is acquired mainly through formal teacher training and during in-service practising after training, the **impactful** PCK (which students turn to subconsciously) for teaching science is **acquired** and **conceptualised** during years of students' being taught and learning of science subject content (coined in this study **entrenched** or **engrained PCK** for teaching science). The findings from this inquiry help to inform the recommendations that educators of science subject content at any level ought to model good science teaching as this is a powerful way of entrenching PCK for science teaching; so that the vicious cycle of poor teaching is broken and not passed from teacher to student, and then from the 'new teacher who was a student' to 'new student'.

References

Bishop, K., & Denley, P. (2007). *Learning Science Teaching: Developing a professional knowledge base*. Open University Press.

Cassidy, S. (2010). Learning Styles: An overview of theories, models, and measures. *Educational Psychology*, *24*(4), 419-444, DOI: 10.1080/0144341042000228834.

Kroll, L. R. (2004). Constructing constructivism: how student-teachers construct ideas of development, knowledge, learning, and teaching. *Teachers and teaching*, *10*(2), 199-221.

Mavhunga, E., & Rollnick, M. (2017). Implementing Pck Topic by Topic in Methodology Courses. In A. J. Sickel, & S. B. Witzig (Eds.), *Designing and Teaching the Secondary Science Methods Course*. SensePublishers, Rotterdam. https://doi.org/10.1007/978-94-6300-881-5_9

Shulman, L. S. (1986). Those who understand knowledge growth in teaching. *Educational Researcher*, *15*(2), 4-14.

Shulman, L. S. (1987). Knowledge growth in teaching: Foundations of the new reform. *Harvard Educational Review*, *57*(1), 1-22.

Taylor, C., & Hamdy, H. (2013). Adult learning theories: Implications for learning and teaching in medical education. *Medical Teacher*, *83*(35), 1561-1572, DOI: 10.3109/0142159X.2013.828153

Vygotsky, L. S. (1978). *Mind and Society: The development of higher psychological processes*. Cambridge, M.A: Harvard University Press.