Strengthening Pedagogical Content Knowledge Of Preservice Physics Teachers: 3 Cases On Electric Circuits

FORTALECIMENTO DO CONTEÚDO DIDÁTICO CONHECIMENTO DOS ALUNOS PROFESSORES DE FÍSICA: 3 CASOS EM CIRCUITOS ELÉTRICOS

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Abstract

This work is part PhD thesis whose objective is that pre-service physics teachers can build or strengthen (at least part of) a Pedagogical Content Knowledge (PCK) in an electromagnetic course. For this purpose, an electromagnetic course was reconstructed based on science education research results that promotes the productive disciplinary involvement of students. We characterize PCK about electric circuits of two students who have taken this reconstructed electromagnetic course. At the same time, the PCK of another student who has taken the electromagnetic course but before it was reconstructed is characterized as well. For the characterization of the PCK, each of the three students involved in this study is asked to elaborate a sequence of activities of two classes on electric circuits and each component of the PCK is analyzed on the basis of a rubric designed for this purpose. The analysis shows that the PCK corresponds to teachers in training, although there are differences among them. The students who took the reconstructed course have a more developed PCK on electric circuits compared to those who took the same course before its reconstruction.

Keywords: Pedagogical Content Knowledge. Preservice Teacher. Electric Circuit

Resumo

Este trabalho é parte de uma tese de doutorado cujo objetivo é permitir que futuros professores possam construir ou fortalecer (pelo menos parte de) um Conhecimento de Conteúdo Didático (CCD) em espaços curriculares de física. Para tanto, um curso de eletromagnetismo foi reconstruído com base em resultados de pesquisas em educação científica que promovem o envolvimento disciplinar produtivo dos alunos. Este trabalho de pesquisa caracteriza o CCD sobre circuitos elétricos de dois estudantes de treinamento de professores que tomaram o curso Fenômenos Eletromagnéticos didaticamente reconstruídos. Ao mesmo tempo, também caracterizamos o CCD de outro estudante que tomou o mesmo assunto, mas antes de ser reconstruído didaticamente. Para a caracterização dos CCD, foi solicitado a cada um dos alunos dos três alunos envolvidos neste estudo que elaborasse uma sequência de atividades de duas aulas sobre circuitos elétricos e cada componente do CCD foi analisado com base em uma rubrica projetada para este fim. A análise mostra que os CCD correspondem aos professores estagiários, embora haja diferenças entre eles. Os alunos que cursaram o curso Fenômenos Eletromagnéticos reconstruídos didaticamente, têm um CCD mais desenvolvido nos circuitos elétricos em comparação com aqueles que cursaram a mesma disciplina mas com uma abordagem didática tradicional.

Palavras-Chave: Conhecimento de conteúdo didático. Treinamento de professores. Circuitos elétricos

Introduction

Preservice teacher education is the place in which future teachers build the necessary tools to 1) understand the physics of scientists and the physics of the school, and 2) to design bridges between them. This requires a broad and deep knowledge of physics, learners, school, classroom life, secondary school curriculum, and teaching resources, etc.. Although the curriculum for preservice teacher training in the Province of Córdoba provides courses in which the above contents are worked on, these courses are very often crystallized in independent "parcels" of knowledge. It is unlikely that without specific courses in which the integration of this knowledge is promoted, future teachers will be able to do it by themselves when making decisions about teaching in real classroom contexts. This "amalgam" of knowledge is what the literature refers to as Pedagogical Content Knowledge (PCK) (Magnusson y otros, 1999, Shulman, 1986). Some researchers point out that the physics education courses would be adequate contexts to build this knowledge, but there is literature that argues that these courses are not enough to achieve this learning, being necessary to use the disciplinary courses to strengthen the PCK of the pre service physics teachers (Mäntylä y Nousiainen, 2013; De Longhi y Rivarosa, 2015).

Local and international research shows that the usual physics teaching is superficial and based on algorithmic problem solving (Leonard et al, 2002, Guisasola, 2011). Designing classes that promote learning where students are productively engaged demands a sophisticated PCK from the physics teacher. It involves simultaneously bringing together a deep knowledge of physics, how students learn, how to manage classroom communication, what are students' interests and prior knowledge, what are teaching purposes, what are the teaching resources, etc. The hypothesis underlying this work is that future teachers can build and/or strengthen (at least part of) their PCK in physics courses, when those courses are designed based on science education results.

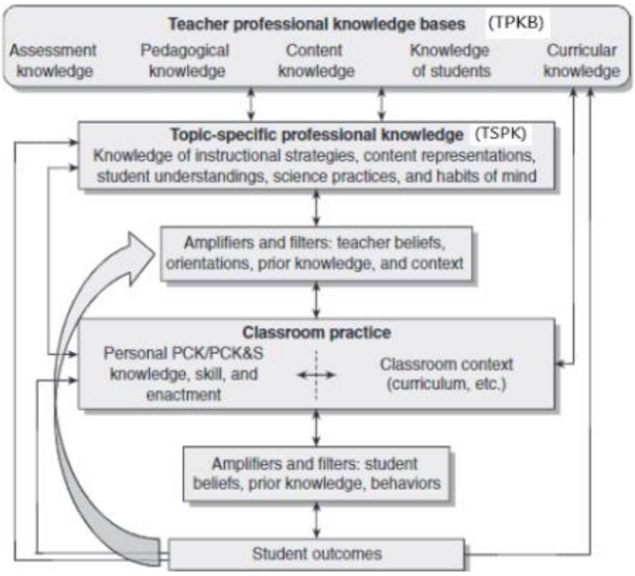
The present work is part of a PhD thesis in which a reconstructed electromagnetism course to preservice physics teachers has been carried out. The reconstruction of the course was based on science education research results The principles used for the reconstruction were exposed by Engle and Conant (pp. 402-406; 2002). The purpose of this reconstruction is that future teachers have the opportunity to experience a teaching oriented to learn about physics and about its teaching simultaneously. This research aims to characterize the PCK on electric circuits of students who have taken the reconstructed course. At the same time, we try to characterize the corresponding PCK of a student who has taken an electromagnetism course in a traditional way of teaching (before its reconstruction). The questions guiding the research are: 1) How is the PCK on electrical circuits of preservice physics teachers who have taken an electromagnetism course? 2) What differences are there between the PCK on electrical circuits of preservice physics teachers who took the reconstructed course, and the corresponding PCK of those who took the electromagnetism course in the traditional way, i.e. before its reconstruction?

1. Theoretical framework

Shulman (1986), breaks with the traditional dualism of two types of knowledge of two disciplinary fields (content/subject and its didactics), to establish a new dualism (knowledge of the subject/didactic knowledge) within the knowledge of the content. Under the denomination of PCK they refer to those aspects of the content, whose knowledge is relevant for teaching, including "the topics that are most regularly taught in an area, the most useful forms of representation of ideas, the most powerful analogies, illustrations, examples, explanations and demonstrations, in short, the way of representing and formulating the subject matter to make it understandable to others" (Shulman, 1986). Shulman's introduction of PCK has inspired numerous responses among education scholars, resulting in several models of PCK.

The multiplicity of PCK models resulted in a PCK Consensus Model (CM) called TPK&S (Teacher Pedagogical Knowledge and Skills) in reference to the first PCK summit held in 2012. As a general description, the TPK&S model (Figure 1) originates in the teacher professional knowledge bases (TPKB) that comprises: knowledge about assessment, about the curriculum, about content, about didactics and the way students learn. This is the generalized professional knowledge that results from science education research and best teaching practices. TPKB knowledge shapes and is informed by Topic-Specific Professional Knowledge (TSPK). In this model, the affective dimension of the teacher is recognized as influencing the teacher's knowledge and skills. The teacher's beliefs about the purposes of science teaching act as amplifiers or filters, and mediate the actions teachers take in the classroom.

Figure 1 -The PCK Consensus Model called TPK&S (Teacher Pedagogical Knowledge and Skills)



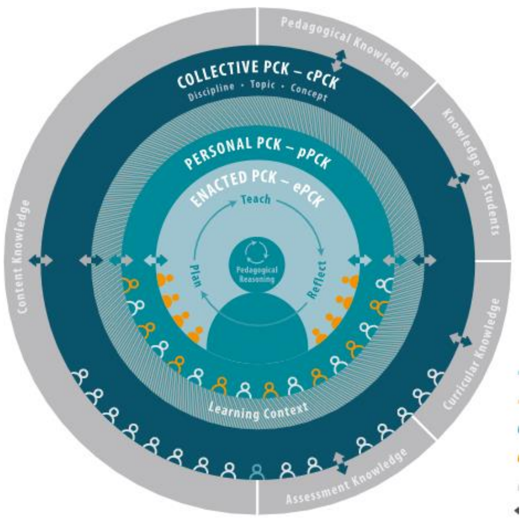
Source: Gess-Newsome, (2015, pp.31)

From this model, it is possible to define PCK as a knowledge base used in the planning and teaching practice of a subject in a very specific classroom context. Finally, the TPK&S model is recursive and dynamic. Both student outcomes and classroom practices have the capacity to inform and shape TSPK and TPKB. These feedback loops underscore the complexities of teaching and learning and provide leverage points for growth in teacher knowledge and skills (Gess-Newsome, 2015).

In 2017, the Refined Consensus Model (RCM) of PCK was created, which builds on the model described above but places greater emphasis on making explicit the different variables, layers, and complexities associated with PCK and highlights in a clearer way the relationship between PCK and teaching practice. A key feature of this model is the identification of three distinct domains of PCK: collective (cPCK), personal (pPCK), and enacted (ePCK), which describe the specialized professional knowledge possessed by multiple educators in a field, the knowledge possessed by an individual science teacher, and the unique subset of knowledge that a teacher relies on to engage in pedagogical reasoning during planning, teaching, and reflecting on a lesson (Figure 2). Inherent in the development of these layers of PCK are the contributions of teachers, students, peers, and others. The model recognizes that the broader professional knowledge bases are fundamental to the science teacher's PCK and that the learning context influences the teaching and learning that takes place in the classroom. Knowledge and skills of cPCK are filtered and amplified in ways that shape personal PCK.(Carlson et al, 2019).

To teach particular content to particular students in a particular context, again moderated by the teacher's own amplifiers and filters, specific professional knowledge is used in teaching practice known as enacted PCK (ePCK). Experiences gained from science teaching practice provide feedback that develops and shapes a science teacher's pPCK. An individual teacher, through conversation and sharing, can contribute to the collective PCK (cPCK) built by a group of teachers or add more canonical knowledge to the field. This flow of knowledge and skills in and out and across concentric circles is a key feature of RCM (Carlson et al, 2019).

Figure 2 - Representation of the PCK Refined Consensus Model (RCM)



Source: Carlson et al (2019, pp. 83)

The pPCK is nourished by those elements belonging to the cPCK that pass through the teacher's filters and amplifiers. Also the pPCK shapes the teaching practice that feeds back into the same pPCK that gives rise to it. Finally another way to strengthen prospective teachers' pPCKs are their own learning experiences of that particular content. The latter is at the heart of the research hypothesis presented in this paper.

2. Context

The research takes place in a physics teaching career. The electromagnetism course and science education course take place at the same time. In the science education course students deal with different topics such as teaching models, classroom discourse and learning by inquiry. The science education class consisted of 5 students of which 3 of them obtained, thanks to their good academic performance, the possibility of accessing a final paper to accredit the course. Of the 3 students (A, B and C), two of them (A and B) took the reconstructed electromagnetic course during that year. On the other hand, student C took the same course the previous year, before it was reconstructed. It is important to note that all students have the same academic career trajectory at the time of this research.

3. Methodology

At the end of the year, those students who had access to the final work of the physics education course had to carry out a sequence of activities of two classes for 16-year-old students on some contents of electric circuits.

Each of the sequences was analyzed based on a rubric created to characterize each student's pPCK. In this case the pPCK is informed from each student's ePCK through their lesson planning. The PCK rubric is an instrument to characterize a teacher's PCK based on observations of the teacher's planning and/or teaching (Park and Oliver. 2008). This instrument was based on a rubric proposed by Carpendale, & Hume, (2019), on the TPKB components of the TPK&S model, and on the teaching bases proposed in the RCM of PCK. The components to be analyzed are:

- Content knowledge
- Knowledge about evaluation
- Knowledge about instructional strategies
- Knowledge about the way in which students learn
- Knowledge about curriculum

Table 1 shows which aspects of each component of the CDP were analyzed. Each of them was assessed using the following scale: Limited, Basic, Proficient and Advanced. Table 1 explains the criteria used for the respective assessment.

Table 1 - Rubric to characterize each component of the PCK

ePCK indicator	Limited	Basic	Competent	Advanced
Knowledge about the curriculum				
Adequacy of concepts in relation to curriculum design	Non-alignment of the concepts worked with those proscribed by the curriculum.	Low alignment of the concepts worked with those proscribed by the curriculum.	Adequate alignment of the concepts worked with those prescribed by the curriculum.	Total alignment of the concepts worked with those proscribed by the curriculum.
Content Knowledge				
Correct scientific explanation of the concepts	Incorrect explanations of most concepts	Inaccurate explanations of most concepts	The explanations are mostly accurate and only minor inaccuracies were observed.	The explanations were precise in all cases.
Links and connections to other concepts	No connections to other concepts are generated	Few connections with other concepts are generated	Most of the possible connections with other concepts are made by	All possible connections to other concepts are made
Links (implicit or explicit) to the Nature of Science and/or Scientific Research	There is no work on NoS or SR..	CI is worked from the experimental activity	Activities in relation to the NdC are incorporated	An epistemological analysis of the way in which scientific knowledge is constructed is carried out.
Knowledge about students' understanding				
The teacher recognizes possible student background knowledge and/or learning difficulties.	It does not foresee activities to gather the students' previous ideas.	An attempt is made to gather previous ideas with open questions about the content to be worked on.	An attempt is made to survey the students' previous ideas by solving activities designed for this purpose, although they may give a spectrum of answers that are difficult to handle.	The students' previous ideas are surveyed with concrete activities and semi-open-ended answers.
Teacher uses students' preconceptions to guide instruction	Students' previous ideas are not taken into account by the teacher.	The previous ideas are contrasted with the teacher's words.	Previous ideas are contrasted with empirical results.	A questioning of the models underpinning prior ideas takes place, giving students the opportunity to progress their ideas.
Teacher probes students' understanding with questions	The teacher does not assess the progress of students' preconceptions.	The teacher states that he/she will be asking the students about their understanding of the topic.	Situations are proposed in which the previously stressed models are used again.	Situations are proposed in which the previously stressed models are used again, and possible paths to take in the sequence are stated according to the students' answers.
Knowledge of instructional strategies				
Appropriate sequencing of concepts	There is no link between one concept and the next.	There is a link but the order of the contents is not appropriate.	The order of the contents is appropriate	The order of the contents is appropriate and takes into account the possible variants that may arise according to the evolution of the class.

Problematizes the content	There is no problematizing activity	Propose an introduction to the topic orally, or with a comparison of characteristics without a problem to solve, or with a video about the phenomenon.	Using a lab or problem to problematize the content	Uses a real problem to problematize content
Uses Labs/Simulations	Does not use laboratories	Uses labs to validate theory	Proposes laboratories as part of the learning process.	It proposes laboratories within the learning process, generating instances of anticipation and hypothesis testing.
Proposed Classroom Speech	The proposal does not provide for student intervention	The proposal foresees only teacher-student interactions, students have little or no interaction between them.	The teacher foresees discussions in small groups and with the whole class on the resolution of the activities.	The teacher foresees discussions with the whole class about the resolution of the activities.
Closing the class	There is no class locking	The closure of the site is unrelated to the activities carried out.	The closing of the class is related to the activities carried out but the students' contributions are not recovered.	The closing of the class is related to the activities carried out and starts from the contributions/conclusions of the students.
Use of strategies that allow metacognition.	There are no instances of metacognition	Implicit instances of metacognition exist	There are instances of explicit metacognition that allow students to assess their prior thinking and progress.	There are instances of explicit metacognition that allow students to assess their previous ideas and their progress. Assessing by comparing the extent of students' prior models and learned models.
Knowledge about evaluation strategies				
Timing and Purpose of Assessing Student Progress	Not evaluated	Only at the end of the sequence in a summative manner in pursuit of accreditation objectives.	Throughout the sequence to assess the progress of students' ideas.	Throughout the sequence to gather feedback on the progress of students' ideas and redirect the proposal accordingly.
Type of evaluation	Questions that aim only at recalling information	Algorithmic problem solving	Open-ended but decontextualized problem solving	Content reconstruction activities based on the resolution of open and contextualized problems.

4. Results and Discussion

After analyzing each of the sequences developed by the preservice physics teachers with the rubric shown in Table 1, the number of aspects that have been classified as limited, basic, proficient and advanced are counted. Some aspects could not be assessed with the information provided by the text of the sequence, and therefore have been categorized as Not distinguishable. Figures 3 and 4 show the results obtained in percentage terms, for each component of PCK analyzed in the sequences elaborated by students A and B respectively.

Figure 3 - PCK results based on student sequence A

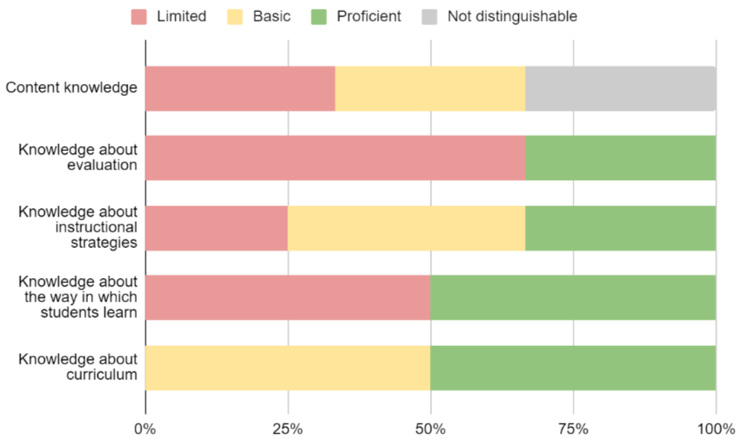
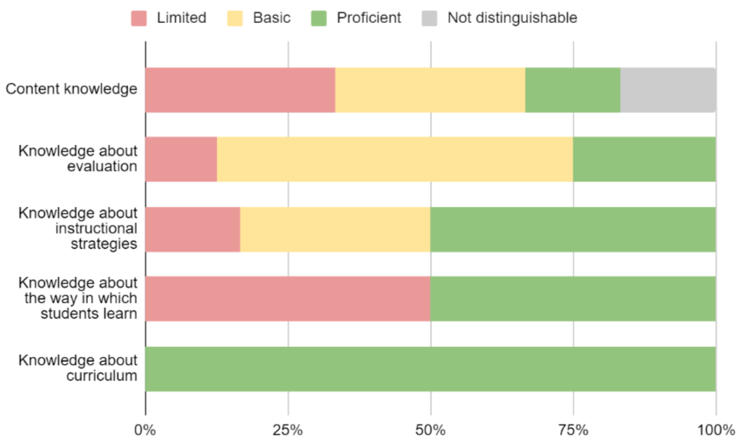
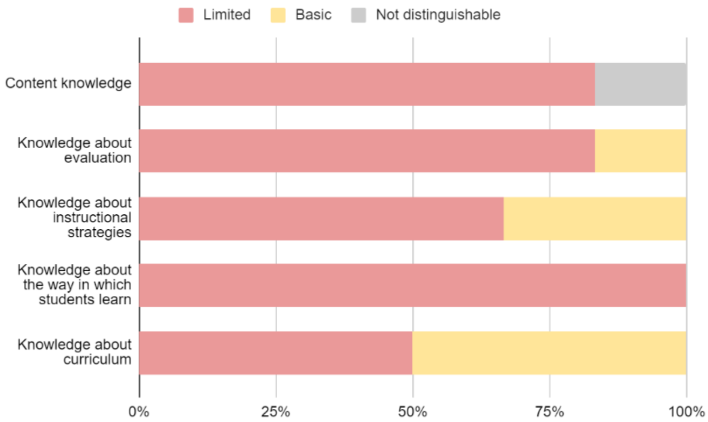


Figure 4 - PCK results based on student sequence B



Both graphs show that knowledge about the discipline in both cases is improvable, since it oscillates in the lowest characterizations. The use of some instructional strategies worked on in the reconstructed electromagnetic course is observed. It is appreciated that the proposals try to consider issues linked to the way in which students learn. There is also evidence of a competent use of evaluation when it is implemented, although not all classes generate evaluation instances. In relation to knowledge of the curriculum, it is observed that students are aware of the official curriculum and align their proposals to those prescribed by said document.

Figure 5 - PCK results based on student sequence C



In this case, it is evident that most of the components of student C's PCK are characterized as limited (Figure 5). It is important to remember that this student has managed to pass the previous subjects, and has reached the final stage of the physics education course due to his academic merits, just like students A and B. Although the knowledge about the discipline can be improved in students A and B, there is a significant difference with student C. This may be due to the fact that students A and B took the reconstructed electromagnetic course and student C did not. A more sophisticated knowledge of students A and B compared to C is observed, both on how students, instructional strategies, assessment strategies and curriculum.

5. Conclusions

Returning to the guiding questions of this research on 1) What is the PCK on electrical circuits of physics preservice teachers, who have taken an electromagnetic course? It is possible to say that the components of the PCK of these students on the topic in question, acquires different degrees of development and it is observed that it is a PCK in formation. That is, an important part of the PCK components are characterized as limited or basic. However, in response to the question 2) What differences exist between the PCK on electrical circuits of the students who took the reconstructed electromagnetic course, and the corresponding PCK of those who took the same course but prior to the reconstruction? Significant differences were observed when comparing the students' PCKs. All the components of the PCK acquire characteristics of further development in students who have taken the reconstructed course compared to those who have taken this subject in its traditional version. Although the research presented is of an exploratory nature and the analysis corresponds to only three cases, the results support what Mavhunga (2019) stated in relation to how promising it can be for the training of future teachers to think of proposals aimed at developing the pPCK topic by topic.

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