The Pedagogical Content Knowledge on Newton's Laws of a Physics teacher, in a professional technical school in Costa Rica

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Abstract

The Pedagogical Content Knowledge (PCK) of a physics teacher from a professional technical school in Costa Rica is reflected. Characterizing its approach to the inclusive obstacles of Teaching Professional Development [5] and showing the way in which it transcends between the technical, practical and critical dimensions of the Complexity Hypothesis (HC) [6], following a qualitative line. The teacher presents a tendency between the practical and critical dimensions, since she considers the emotional climate that is generated in the classroom relevant, as a fundamental element for the students' motivation and interest in learning. In addition, the implementation of technological resources such as simulations, experimentation with easily obtained materials and the future development of interdisciplinary projects, which makes it go beyond the framework of the traditional physics class, in which only dictated or taught problems are solved text book.

Keywords: Professional development, Newton's Laws, Hypothesis of Complexity, Case study.

Resumen

Se plasma el Conocimiento Didáctico del Contenido (CDC) de una profesora de física de un colegio técnico profesional de Costa Rica. Caracterizando su abordaje ante los obstáculos inclusivos del Desarrollo Profesional Docente [5] y mostrando la forma en que transciende entre las dimensiones técnica, práctica y crítica de la Hipótesis de la Complejidad (HC) [6], siguiendo una línea cualitativa. La profesora, presenta una tendencia entre las dimensiones práctica y crítica, puesto que considera relevante el clima emocional que se genera en el aula, como elemento fundamental para la motivación e interés por aprender de los estudiantes. Además, de la implementación de recursos tecnológicos como simulaciones, experimentación con materiales de fácil obtención y el futuro desarrollo de proyectos interdisciplinarios, lo que hace que se salga del marco de la clase tradicional de física, en la que solo se resuelven problemas dictados o del libro del texto.

Palabras clave: Desarrollo profesional, Leyes de Newton, Hipótesis de la Complejidad, Estudio de caso.

I. INTRODUCTION

Pedagogical Content Knowledge (PCK) is a very important aspect for physics teachers, since this subject is the basis of modern society, and provides development in critical thinking and the ability to reason and solve problems [1]. That is why it must be considered both in initial training and in their work tasks. The PCK is defined as the alloy between the content of the discipline with other pedagogical knowledge [2]. Later, PCK research was developed aimed at teaching Natural Sciences, in which new systems of PCK categories were proposed [3], which considered aspects such as guidelines on science teaching, curricular knowledge in science, knowledge on students' understanding of science, knowledge of science teaching strategies, knowledge of science assessment. Subsequently, a more integrative Didactic Content Knowledge model emerges that encompasses the previous approaches in a more refined way, in addition to adding fundamental elements such as personal PCK and PCK and skill [4]. In this study, the Pedagogical Content Knowledge of a physics teacher from a technical school on Newton's laws will be described.

II. MARCO TEÓRICO

A. Pedagogical Content Knowledge

Pedagogical Content Knowledge (PCK) is an intrinsic aspect of teachers [4], corresponding to a main knowledge to plan the teaching of a particular topic and its development in the classroom, placing this conception of PCK with the Teacher Professional Knowledge Bases (TPKB), together with the Topic Specific Professional Knowledge (TSPK), as seen in figure 1.

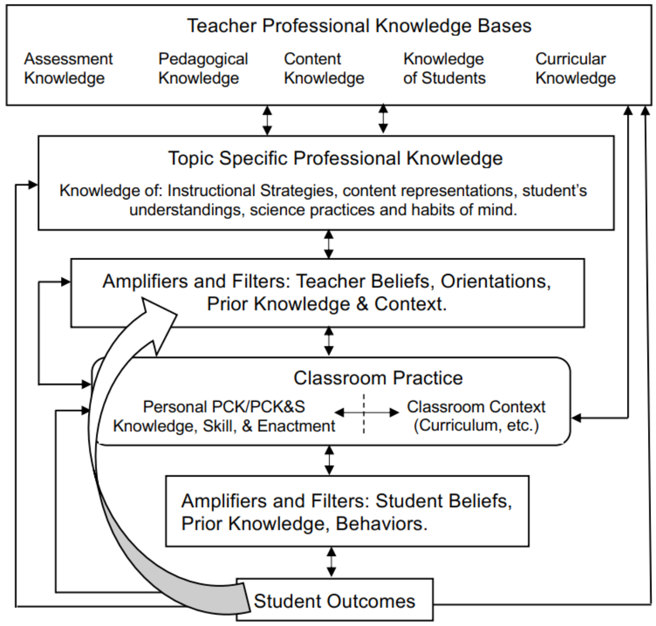

FIGURE 1. Model of Pedagogical Content Knowledge [5].

B. Teacher Professional Development

Teaching Professional Development (TPD) is the knowledge that integrates theory and practical experience [5], in a singular epistemology under a specific interpretive framework. Encompassing the knowledge of teachers, not only of the contents to be taught, but of the didactics associated with them, through not only what was taught in their training, but also what they learned through their professional experience, by example of the exchange with colleagues, students and of course from their own experience. Likewise, over time, obstacles emerge in TPD, such as beliefs and personal practical knowledge that are stable and consolidated in professional activity, resistant to change [5]. Among these obstacles, the inclusive ones represented in figure 2 stand out:

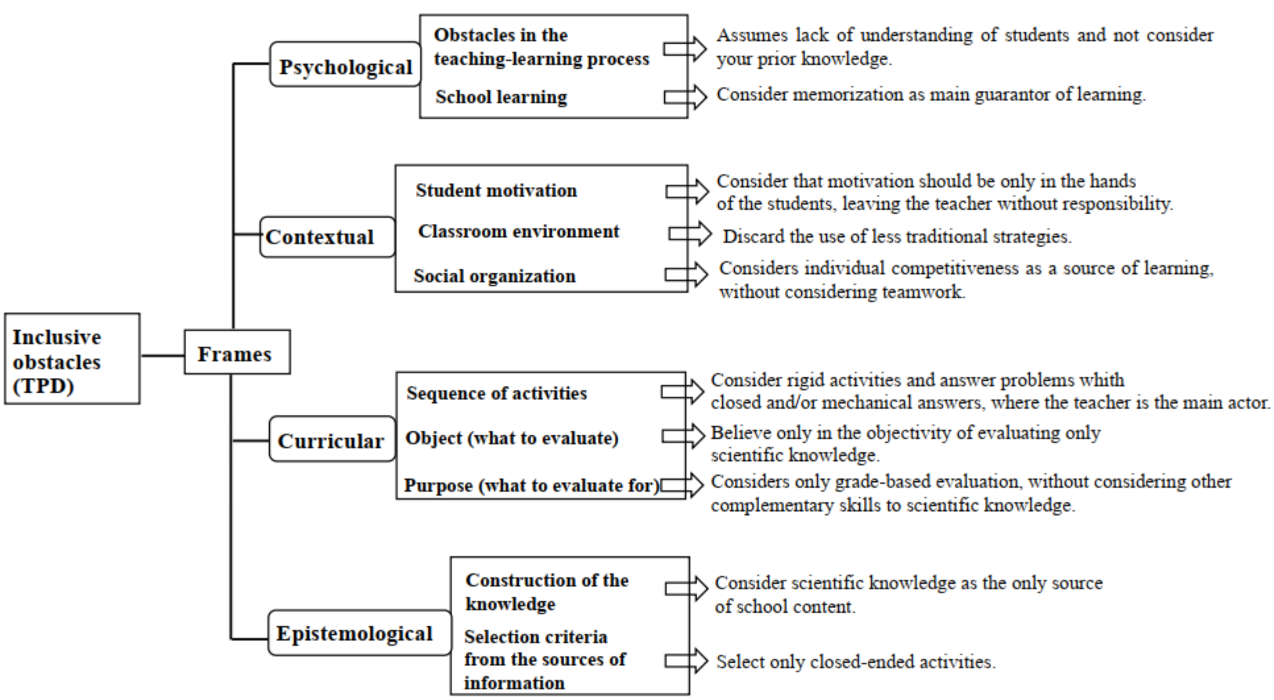

FIGURE 2. Inclusive obstacles, adapted from [5].

C. Complexity Hypothesis

The Complexity Hypothesis (HC) is understood as the evolution in the capacity for interaction with the social or natural environment, through reflection-practice integration and that affects ideological, training, contextual, epistemological and curricular aspects [6]. Composed of three dimensions: technique, practice and criticism, described in table I, which consistently transcend, while adding increasing complexity during the pedagogical mediation processes [7].

TABLE I. Dimensions of the Complexity Hypothesis.

Dimension	Description
Technique	The teaching staff limits itself to the use of closed problems with mechanical and rote resolutions, prioritizing conceptual understanding.
Practical	Coexistence of closed and open problems, which allows conceptual understanding, allowing the teacher flexibility and adaptability in the class context.
Criticism	It enhances the use of research problems, leading to an improvement in educational practices for the teacher.

Note: Adapted from [6].

III. METHODOLOGY

The study focused on capturing the teacher's PCK when planning and developing the topic of Newton's Laws in her lessons. Therefore, the case study was used, defined as something specific that focuses on following consistent and sequential patterns of behavior [8].

To capture the PCK, a questionnaire was used based on the Content Representations (CoRe) [9], related to the Teacher Professional Knowledge Bases (TPKB) [6] shown in figure 1, sent to the teacher by email and designed in Google Forms, which was validated by the criteria of experts in experimental science teaching. Likewise, the research is framed in a qualitative line and within the paradigm of evolutionary complexity, defined as the way of perception of the teacher's development, and which provides a level of complex reasoning translating into personal and social maturity [10].

As for the teacher, she has 17 years of experience, her education from primary to university was developed in a public education context, she has a bachelor's degree in Natural Sciences Teaching, a bachelor’s degree in teaching and a diploma in primary education. While the educational context in which she works as a teacher is a professional technical school, in Costa Rica, which is responsible for training in technical studies in areas such as electronics, computing, agribusiness, secretarial work, among others; in parallel with academic studies, during a period of three school years: tenth, eleventh and twelfth. Being the tenth year where only the subject of physics is developed, leaving biology and chemistry for the other levels.

Below are some of the questions used to capture the teacher's PCK:

TABLE II. Questions that make up part of the questionnaire.

TPKB	Questions
Assessment Knowledge	1.In what way and with what instruments do you evaluate and/or would you evaluate the content of Newton's Laws?
Pedagogical Knowledge	2.How does the first class on Newton's Laws begin, with questions or problematic situations, does it show relationships with the history and nature of science and/or relationships between Science, Technology and Society?
Content Knowledge	3.What difficulties or limitations do you face as a teacher when teaching Newton's Laws?
Knowledge of Students	4.Considera las emociones de los estudiantes en la mediación pedagógica? Do you consider students' emotions in pedagogical mediation?
Curricular Knowledge	5.What other physics content are Newton's Laws related to? Do they depend on these for their explanation and learning?

Note: the complete questionnaire can be seen through: https://forms.gle/9ewJ75461podR3p77.

III. RESULTS

Table III below shows the teacher's responses to the questions in Table II:

TABLE III. Teacher's answers.

TPKB	Answers
Assessment Knowledge	1. Qualitative evaluation, through the explanation of the topic, scientific communication and presentation to classmates, as well as asking problems or questions on the board together, which allows developing scientific language and promoting trust between them. On the other hand, the summative, with the use of evaluation instruments (homework, practices and exams), as provided by the Ministry of Public Education (MEP).
Pedagogical Knowledge	2.With a review of previous knowledge and the relationship with everyday actions, with a problematic situation or by asking a generating question that opens up to an analysis of a situation.
Content Knowledge	3.The lack of physics laboratories, little scientific language, problems with reading comprehension and handling of basic mathematical operations in students. As well as excess of students per section.
Knowledge of Students	4.The emotional climate is essential, since it goes hand in hand with motivation and interest in learning; students who feel comfortable learn better.
Curricular Knowledge	5.Electricity with the similarity of the formulas.

From the above, together with other responses provided by the teacher, their PCK is formed, see figure 3, in which they highlight their interest in maintaining a motivating environment, so that the students maintain their interest in learning. Likewise, it seeks to maintain a balance between summative and formative evaluation.

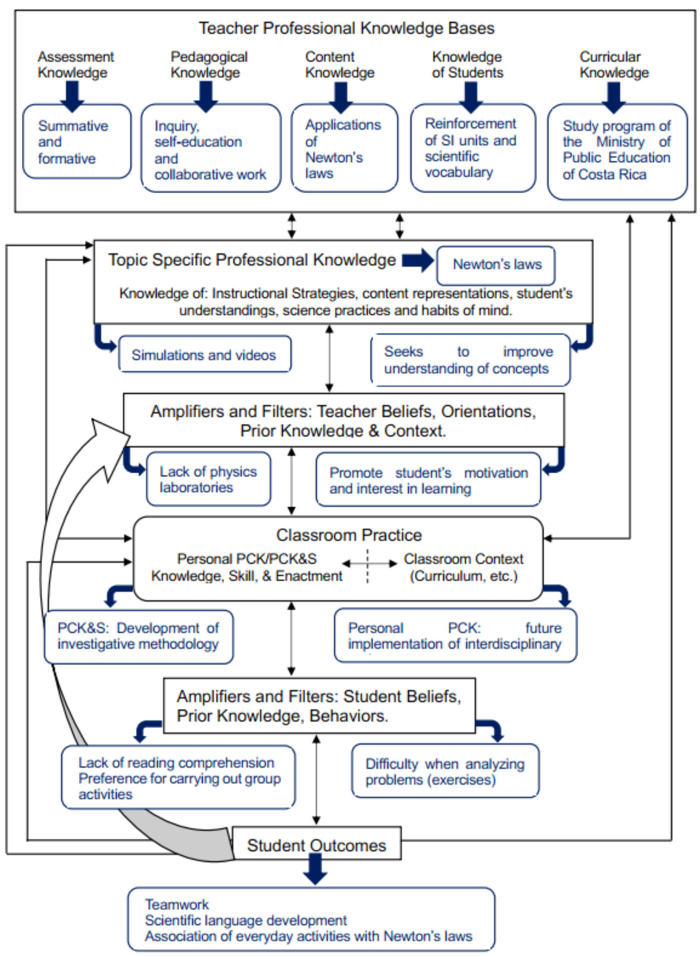

FIGURE 3. Teacher PCK model. Note: SI = International System of Units.

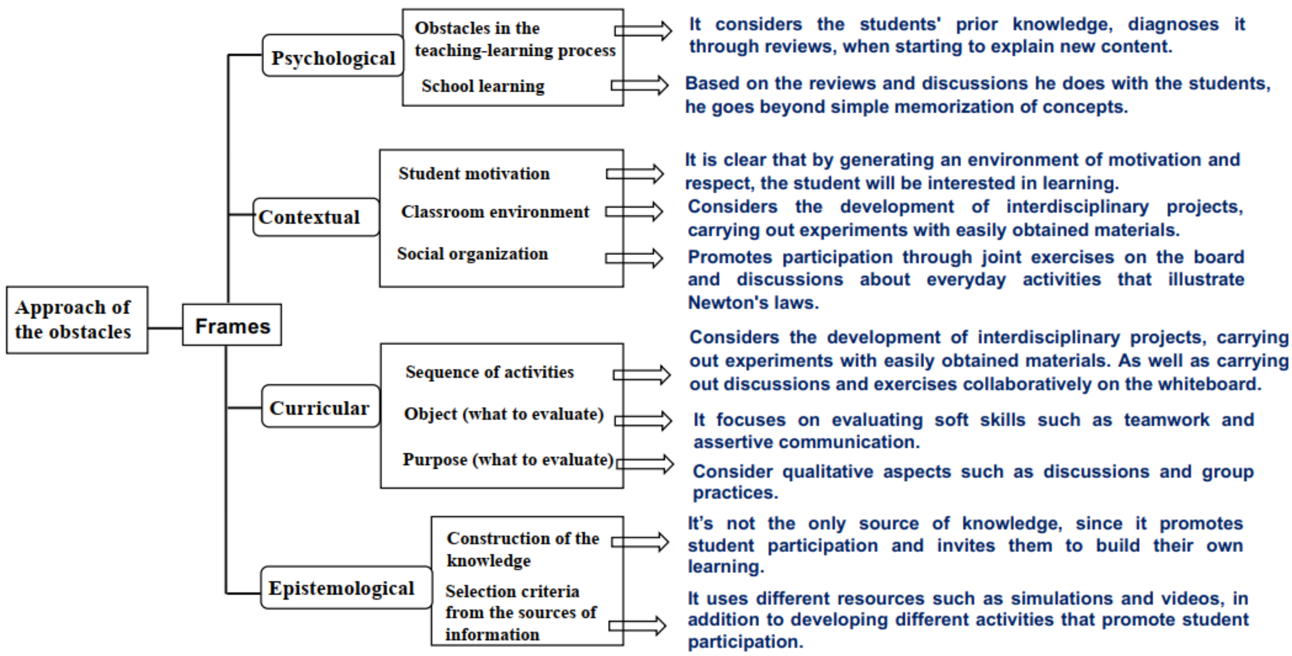

FIGURE 4. Teacher's approaches to TPD obstacles.

Starting with the psychological framework, it is noted that the teacher does consider the students' prior knowledge, including diagnosis through different activities such as reviews and reflections before beginning to explain a certain content. Regarding the contextual framework, there is an interest in keeping students motivated, in addition to maintaining a classroom environment based on respect, since it is considered that in this way, they will be more motivated and comfortable to learn, it also does not rule out maintaining that interest. the future development of interdisciplinary projects that involve other areas of knowledge. Hence, the curriculum considers the evaluation of soft skills such as teamwork and the students' ways of expression and communication. Finally, in the epistemological framework, the teacher is not considered the main source of knowledge, on the contrary, she empowers the students to be builders of their own learning, through reflections and discussions in class, as well as the use of resources didactic such as simulations and videos.

Thus, the teacher positions herself between the practical and critical dimensions, since she does not focus on the realization of problems with closed answers, rather she promotes discussion and reflection on these and the respective concepts they address. such as normal force, friction, acceleration, weight, among others. In addition, it considers skills such as teamwork, while developing and enhancing the scientific and conceptual skills of the discipline of Physics. The following figure shows the significance between dimensions of the teacher:

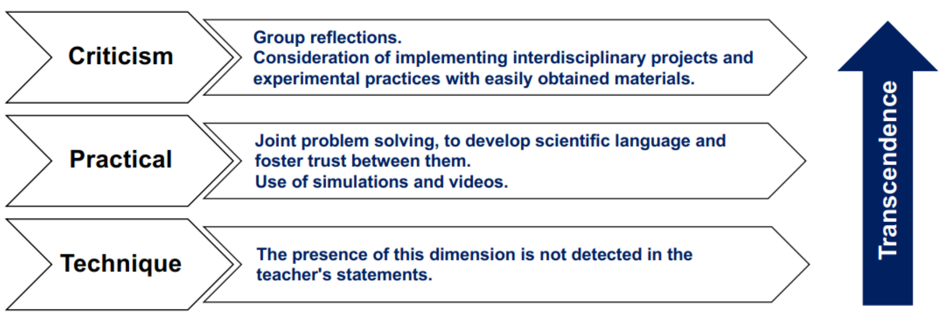

FIGURE 5. Transcendence between dimensions of the teacher's HC.

These actions cause the teacher to generate a more dynamic environment in her classes, by carrying out experiments to explain the concepts of force and movement. For example, with elements as simple as a pencil and the table to demonstrate the inertia of the pencil, noticing that it remained still and then moved when applying a force on it, hand in hand with group reflections and joint completion of problems.

IV. CONCLUSIONS

The teacher goes outside the framework of traditional physics classes, due to the way she addresses the different inclusive obstacles of Teaching Professional Development (TPD), by considering the students' prior knowledge relevant and not based solely on the memorization of concepts. On the contrary, it encourages the construction of their own learning, by carrying out discussions and solving problems jointly and in groups, framing itself as a guide during pedagogical mediation rather than a transmitter of disciplinary knowledge. Hence, its Pedagogical Content Knowledge (PCK) is characterized by implementing the inquiry methodology in its classes, to maintain a more active role of the students, while being willing to consider the future development of new activities such as the development of interdisciplinary projects and tours to research laboratories. For this reason, the teacher presents the significance between the practical and critical dimensions, in addition to promoting the development of skills such as assertive communication, critical thinking, systemic thinking and teamwork in students, using teaching physics, particularly Newton's laws as a means.

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