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Examining pedagogical knowledge content on mitosis in a University context

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Abstract
Mitosis is a process of cell division occurring in eukaryotic organisms. Students from many countries experience difficulties learning this science topic, and its teaching demands substantial effort. Effective teachers develop a wide range of knowledge types to successfully transform science matter for students; this transformation of knowledge has been conceptualized as pedagogical content knowledge (PCK). In this study the PCK of two University teachers on mitosis was explored. As informed by the instruments employed (Content Representation and Pedagogical (CoRe), and Professional experiences Repertoires, analytical rubric (PaP-eR), and semi-structured interviews) both participants' PCK on mitosis can be characterized as incomplete, however not identical. PCK evolves throughout the professional practice so, in a context mostly limited to a traditional teacher-centered transmission of knowledge such as the university, development of teachers' PCK emerges as a strategy to re-orient the teaching of mitosis to modalities based on the construction of scaffoldings to facilitate students' learning.

Keywords
Pedagogical content knowledge (PCK), mitosis, university, Content Representation questionnaire (CoRe), Professional and Pedagogical experience Repertoire (PaP-eR)

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1. Introduction

Mitosis is a process of nuclear division in eukaryotic cells that occurs when a single parent cell divides resulting in generally two identical daughter cells each containing the same number of chromosomes and genetic content as that of the original cell. During cell division, mitosis refers specifically to the separation of the duplicated genetic material carried in the nucleus. This biological process is located at the intersection of unifying topics of biology i.e. continuity, in connection to reproduction, and development of cells and organisms for it relates to growth, tissue repair and regeneration. Learning mitosis is also fundamental to the understanding of transmission genetics and molecular biology (Ayuso and Banet; 2002; Locke and McDermid, 2005). Students from many countries experience difficulties particularly when discriminating biological concepts such as chromosomes, chromatids, diploid cells, and struggle to make appropriate and meaningful connections between mitosis and genetic information (Lewis, Leach and Wood-Robinson 2000; Dikmenli, 2010; Chattopadhyay, 2012; Çimer, 2012).

Different strategies have been proposed to teach this topic, i.e. interactive videos (Baggott and Wright, 1996), chromosomal modeling by using pool noodles (Locke and McDermid, 2005), and socks (Chinnici, Neth and Sherman, 2006), computer-based activities (Tsui and Treagust, 2013), Web-based curriculum units (Williams, Montgomery and Manokore, 2012), and also role-playing (Chinnici, Yue and Torres, 2004). In large university classes, lecturers apply to visualizations of this cell division, among many those supported on PowerPoint® slide shows (González et al., 2014c).

More than three decades ago teachers rated mitosis as one of the most difficult topics to teach (Finley, Stewart and Yarroch, 1982). As students experience difficulties when learning this topic, its teaching demands considerable effort for novice (Yip, 1998) or even experienced teachers (Knippels, Waarlo and Boersma, 2005; Oztap, Ozay and Oztap, 2003; González and Rossi, 2015).

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Many studies conclude that teachers' performance in the classroom is one of the most important factors in students' academic achievement. Thus, effective teachers develop and display a wide range of knowledge types to successfully transform science matter for students (Kind, 2009). Magnusson, Krajcick and Borko (1999) define this type of knowledge as pedagogical content knowledge (PCK): "*the transformation of several types of knowledge from other domains*" (p. 96).

Our research team has been working in the assessment of teachers' PCK on meiosis, a eukaryotic type of cell division process that shares with mitosis similar difficulties as those mentioned above and challenges for both students and faculty. We have successfully employed the Loughran, Mulhall and Berry (2004) Content Representation and Pedagogical, and Professional experiences Repertoires (CoRe and PaP-eRs, respectively) to characterize the PCK of pre-service and in-service secondary teachers on meiosis (González and Rossi, 2014a). In the same line of work, we employed a rubric to document university cell biology teachers' PCK focusing on the PowerPoint® presentation they used in their classes (González et al., 2014c).

Few works examine teachers' PCK on mitosis and are mainly focused on secondary education. The objectives of this study were to document the PCK of two cell biology university teachers on the subject of mitosis following the methodology proposed by Loughran et al. (2004), and complementarily to assess their PCK as displayed in a set of slides.

The research questions guiding the investigation were:

What components of PCK on mitosis can be identified in a University context?

What PCK content can be identified by an analytical rubric assessing a PowerPoint presentation on mitosis?

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2. Conceptual framework

Pedagogical content knowledge (PCK) as proposed originally by Shulman (1986) includes "*the most powerful analogies, illustrations, examples, explanations, and demonstrations in a word, the ways of representing and formulating the subject that makes it comprehensible for others*" (1986, p. 9).

PCK has been interpreted by scholars in many ways addressing different features of it. Kind (2009) reviews a variety of models of PCK including those that follow Shulman's line of thought explicitly and others that draw on empirical research findings or on principles from psychology. The Magnusson et al. (1999) model is within the former group. These researchers conceptualize PCK as consisting of five components: (a) orientations toward science teaching, (b) knowledge and beliefs about the science curriculum, (c) knowledge and beliefs about students' understanding of specific science topics, (d) knowledge and beliefs about of assessment in science, and (e) knowledge and beliefs about instructional strategies for teaching science.

In 2012, international research teams gathered at a PCK summit and produced the following consensus definition: PCK is a "*personal attribute of a teacher, considered both a knowledge base and an action. It is the knowledge of, reasoning behind, planning for, and enactment of teaching a particular topic in a particular way for a particular reason to particular students for enhanced student outcomes*" (Carlson and Gess-Newsome, 2013). As stated by participants at the PCK summit, teacher professional knowledge bases are the backbone of the profession thus including assessment knowledge, pedagogical knowledge, content knowledge, knowledge of students, and curricular knowledge. More interestingly, as depicted in Figure 1, in the classroom practice, PCK interacts with the classroom context, and with two sets of amplifiers and filters. Amplifiers increase the potential of an idea being accepted or an action being implemented whereas filters can extinguish good intentions or ideas. One set of amplifiers and filters comprises teachers' beliefs and orientations; the other set relates to students' beliefs, prior knowledge, and behaviors.

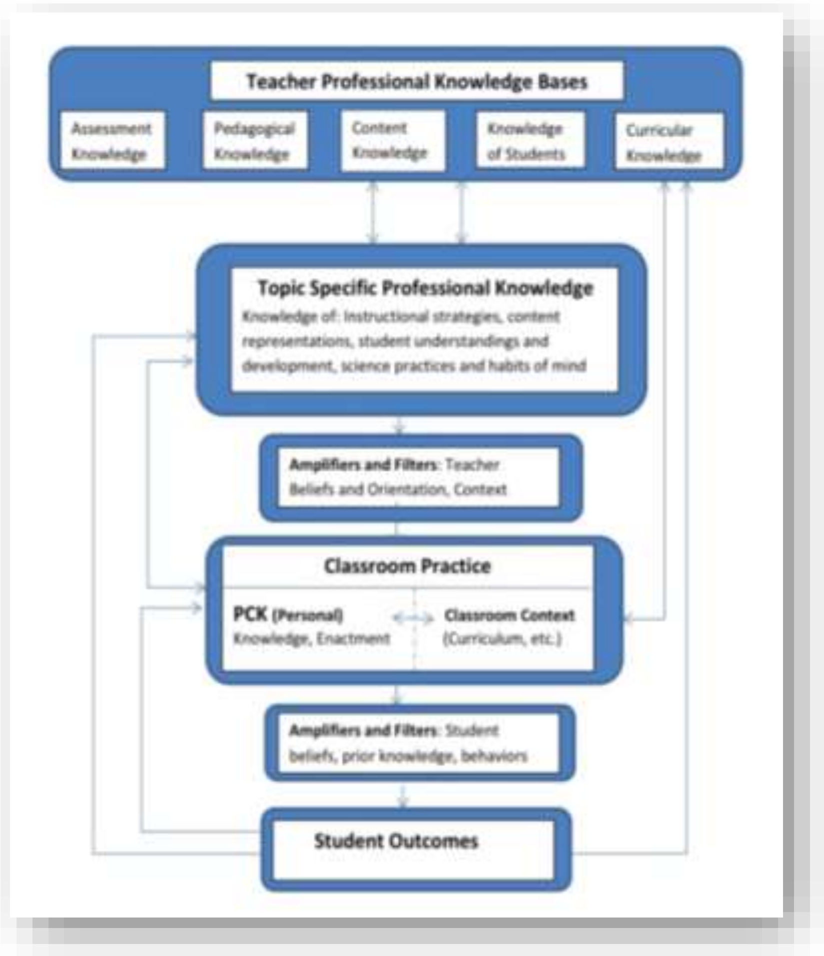

Figure 1. The teacher professional knowledge bases consist in a series of knowledges. Topic Specific Professional Knowledge is derived from a cross section of the Teacher Professional Knowledge Bases for a specific topic. There are two sets of amplifiers and filters, the first set falls between topic specific subject matter professional knowledge and Classroom Practice; the second set falls between the latter and students outcomes. Classroom Practice is the context in which PCK exists.

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3. Methodology

3.1 Context of the study

The study took place in the Veterinary College, University of La Plata, Argentina during a 3 h weekly instruction period of a Cell Biology course. It is a mandatory course for first year students.

Mitosis is a topic included in the course curriculum that is focused mainly on cytological aspects and corresponds to a teaching sequence after dealing with basic genetics, i.e. DNA replication, transcription, protein synthesis, and DNA recombination. It is presented to the students as the final phase of the cell-cycle. Mendelian genetics are covered in a separate second year course.

3.2 Participants

Two teachers (Sylvia and Juliette, pseudonyms) participated voluntarily in the study. Both graduated as Veterinary Medical Doctors and earned their Ph.D. where the study took place and have had very little non-systematic teaching training. They have taught the Cell Biology course as teaching assistants since 2006, and are thoughtful about their classroom performance and highly appreciated by their students and colleagues. Sylvia's and Juliette's classes had 30 and 21 students, respectively.

3.3 Instruments

PCK researchers have developed an array of methodologies and techniques to gain knowledge into this construct, e.g. paper and pencil assessments such as open-ended and multiple choice questions, concept maps, drawings, interviews, video observations of real instruction, classroom observations, and very commonly, some kind of combination of the previously mentioned (Baxter and Lederman, 1999; Borowski, Carlson, Fischer, Henze, Gess-Newsome, Kirschner and Van Driel, 2012).

In this study four instruments were employed. Two of them corresponded to the Loughran et al. (2004) CoRe and PaP-eR tools. The CoRe consisted of eight questions (see Results section). The CoRe questionnaire was presented to the participants and discussed to orientate the elaboration of responses after the class observation. Later, it was sent by e-mail, and answers received a week later by the same via.

The PaP-eR was developed from observations of classes, one of the sources proposed by Loughran et al. (2004). The researchers, as non-participant observers, took detailed field notes and produced shortly afterwards a written version of the material originally gathered at the class.

The third instrument employed was the analytical rubric (González et al., 2014c). It comprised a content dimension focused on PCK whereas the other dimensions aimed to the design of the slides as instructional materials. Briefly, the rubric covered the following dimensions and indicators:

- *Content*: core conceptualizations (identified by a previous inquiry with expert colleagues), logical sequencing, relations between core conceptualizations, transition between concepts, data and/or examples inclusion.
- *Organization*: introduction-body-conclusion format, transition between slides, and internal coherence.
- *Information*: quantity, quality, and pertinence of data.
- *Graphic aspects*: quality, quantity, relevance and creative use of photographs, graphics and tables.
- *Textual aspects*: grammar and spelling, terminology, quality and extent of texts and titles.

Four levels were established for the assessment: exemplary, proficient, acceptable, and unacceptable. Each indicator was assigned 3, 2, 1 or 0 points, respectively.

The PowerPoint® slides were kindly provided by the teachers. The assessment was performed independently by the researchers, and latter discussed so that scorings were consensual.

The fourth instrument included in this study was a semi-structured interview. Sylvia and Juliette were interviewed individually to review their answers to CoRe, and specific aspects of their classes and presentation slides. Then, the final analysis of the CoRe responses, the writing of PaP-eR and the scoring by the rubric were performed.

4. Results

4.1 CoRe

For clarity, Sylvia's and Juliette's responses are presented together with the questions.

1. What do you intend the students to learn about this topic? Our two participants' central ideas are presented in Table 1.

Table 1. The two participant's central ideas on mitosis.

Sylvia´s central ideas	Juliette´s central ideas
• Mitosis is a regulated process that occurs in unicellular and multicellular eukaryotic organisms.	• Mitosis occurs in somatic cells e.g. keratinocytes (epidermal cells), hepatocytes (liver cells).
• Every cell originates from another existing cell like it (Virchow´s *Omnis cellula e cellula*).	• The chromatids of a replicated chromosome separate in the anaphase.
• In dividing cells, mitosis is the culmination of their cell-cycle.	• Daughter cells in mitosis are genetically identical to the parent cell and the reasons for this.
• In mitosis, the parent cell transfers its genetic material previously replicated to daughter cells.	• The comparison of cell division by mitosis and cell division by meiosis.
• Daughter cells originated by mitosis maintain the diploid number of chromosomes of the parent cell.	
• The sequence of events in mitosis is continuous; it is divided into stages mainly for didactic reasons.	

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2. Why is it important for the students to know this? Sylvia stated that mitosis is a basic knowledge related to several biological concepts such as haploid and diploid cells, and processes like cell division by meiosis, and diploid chromosomal number restoration at fertilization. She highlighted that mitosis also provides knowledge basis for the understanding of molecular and cellular foundations of many diseases in which cell proliferation is altered. Juliette's answer referred to the role of mitosis in animals i.e. in development, growth, reparation and regeneration processes; she also mentioned its role in the reproduction of unicellular organisms.

3. What else do you know about this idea (that you don't intend students to know yet)? Sylvia referred to a large body of knowledge on mitosis regulation, e.g. cascades of protein phosphorylation, the groups and subtypes of cyclin proteins family, and the metaphase-anaphase checkpoint. She also linked failures of the cell-cycle machinery to cancer development. As her colleague, Juliette listed a number of molecular aspects of mitosis, the majority of them mostly in relation to chromosome structure (cohesines, condensines). She considered these topics should be addressed in the lectures given by professors.

4. Which difficulties/limitations are connected with teaching this topic? The main difficulties (items 1, 2, and 3), and limitations (item 4) pointed out by Sylvia and Juliette are summarized in Table 2.

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Table 2. Condensed main difficulties and limitations referred by Sylvia and Juliette.

Item	Sylvia	Juliette
1. The complex terminology as a main obstacle, i.e. chromatin, chromosome and chromatid, a set of terms closely similar for students although accurate in the domain-specific vocabulary.	x	x
2. Misunderstanding in the timing of DNA replication, metaphase alignment and anaphasic migration of chromosomes.	x	x
3. Deficiencies in the students' understanding of the cell-cycle regulation at the molecular level.	x	
4. Students generally are not able to develop an adequate insight of mitosis within the cell-cycle.	x	x
5. As cell division is considered a difficult topic, students' involvement in learning is minimal.		x

5. Knowledge about students' thinking that influences your teaching of this topic. From her teaching experience, Sylvia mentioned those common students´ misconceptions referred as difficulties and limitations in the fourth question. Additionally, she pointed out that the identification of those misconceptions can be used as a base to plan lessons. Juliette observed that students generally acknowledge the definition of mitosis –as the one presented in the introduction- and she takes advantage of this fact as a stepping stone to start the lesson and help students to build and deepen their knowledge of the topic.

6. Which other factors influence your teaching of this topic? Sylvia believed teaching mitosis requires initially two major decisions about its approach: mitosis can be focused from different points of view such as the course context in the curriculum, and the time assigned to cover this topic. For Juliette a conditioning factor is the absence of students' previous knowledge of mitosis, i.e. the lack of the stepping stone she mentioned in her previous answer that restricts her students' progress. She also highlighted that students' attitudes of indifference or disinterest are a challenge to her classroom management effectiveness.

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7. Teaching procedures (and particular reasons for using these to engage with this topic). Sylvia answered by means of a list of activities that can be parted as before- and in-class activities. *Before-class activities* included the students' reading from their textbooks and doing assigned homework to revise previous concepts needed for the new topic and practice new ones as a way to engage their participation in class. *In-class activities* comprised a set of tasks dealing with factual knowledge such as changes in the nuclear compartment, number of chromosomes and chromatids, identification of mitosis phases, cytoplasmic changes e.g. in the cytoskeleton, the cell-cycle regulation, and differences between mitosis of plants and animals. These learning tasks include written explanations, simple mathematical calculations, and description of images of dividing cells. Juliette stated that she intends to engage students by pointing out the relevance of mitosis as a more detailed explanation of the processes mentioned in her second answer, linking it to veterinary medicine, e.g. liver regeneration in domestic animals after ingestion of a toxicant.

8. Specific ways of ascertaining students' understanding or confusion around this topic. Sylvia assesses diverse aspects of mitosis by oral questioning in class (e.g. for ploidy: *If a cell has a 38 diploid number, which is the ploidy and number of chromosomes in the daughter cells*?). She also encourages her students to analyze, compare and discuss the mitosis stages depicted in the slides used in class as a way to explicit misconceptions held by students. Juliette mused on how she relies on oral questioning during the class; moreover she employs questions to provide some scaffolding when students summarize the contents covered in class. Questions quoted by Juliette were similar to Sylvia's.

4.2 PaP-eR

For brevity, one PaP-eR was constructed as a condensed, narrative, and comparative report extracted from the class observation notes. For clarity, the teaching sequences were depicted in two graphic representations (Fig. 2).

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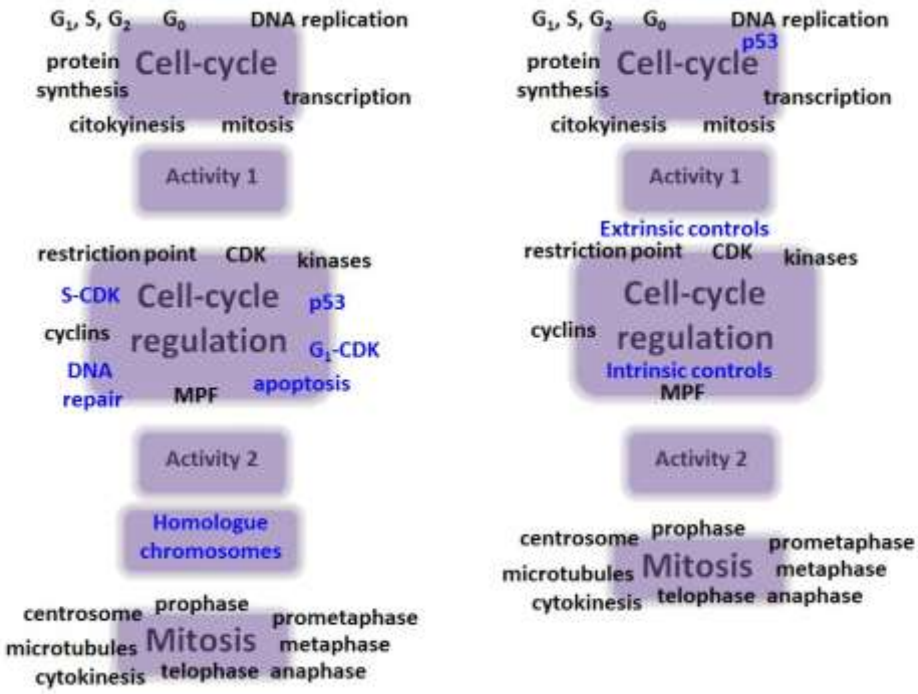

Figure 2. Sylvia´s (left) and Juliette´s (right) teaching sequences developed at the session. Differences found were highlighted in a blue font.

The sessions were carried out following a lecture and solving activities format. Subject matter was presented with a set of PowerPoint® slides. A short introduction for the session included the explanation of the learning objectives and the contextualization of mitosis (and meiosis) within the conceptual frame of sexual and asexual reproductions. After lecturing on cell-cycle, teachers presented the students an activity to assess their understanding and keep up their attention. It consisted in some questions presented in a slide (Fig. 3) on how to differentiate cells in some phases of the cell-cycle. Students engaged for ten minutes in small collaborative groups to discuss and elaborate their answers. During the following minutes students presented verbally their responses; teachers acted as moderators and posed additional questions to promote further discussion and understanding.

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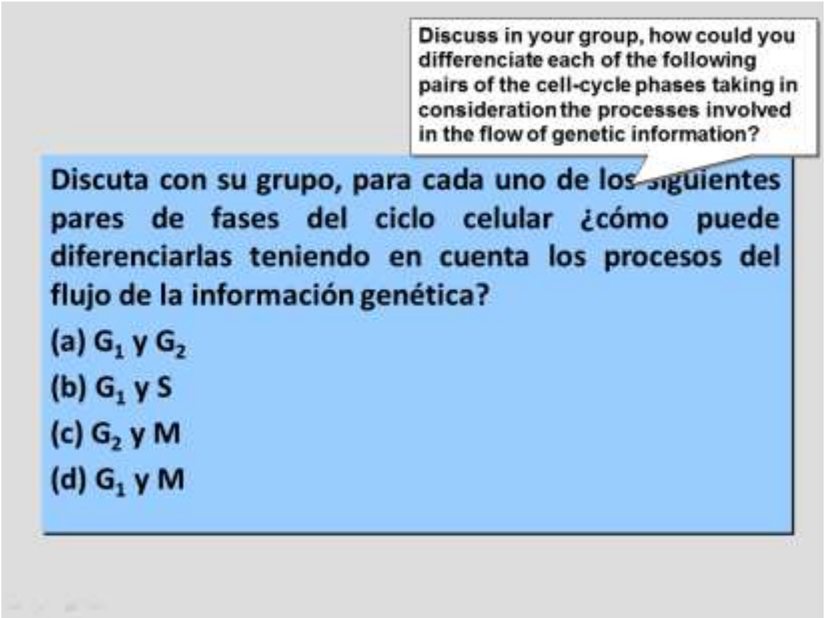

Figure 3. First activity presented to the students in the session. The expected responses involve the occurrence of RNA, DNA and protein synthesis at specific phases of the cell-cycle, e.g. DNA is synthesized only in the S phase so it can be employed to differentiate G1 phase of S phase.

The next subtopic explained by both teachers was the cell-cycle regulation, its processes and checkpoints. The explanation relied on molecular and cellular aspects, viz. kinases and cyclins; those contents were developed in a more extended segment by Sylvia.

A second activity regarding the ploidy and homologous chromosomes concepts was then introduced. It was a short problem, consisting of two questions about a hypothetical cell (Fig. 4). A designated student of each group presented the answers to the class.

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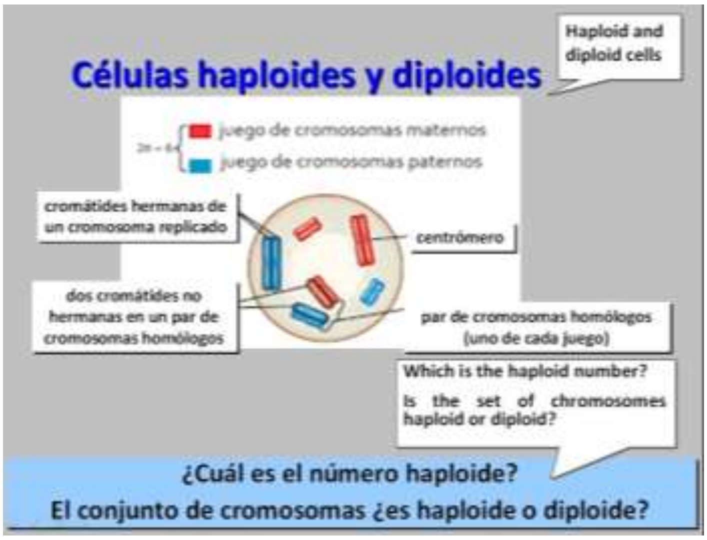

Figure 4. Second activity presented to the students in the session. Expected answers are (a) the haploid number is 3, and (b) the set of chromosomes is haploid.

The last lecture segment was about the cytological aspects of mitosis. Sylvia revised the organization of the interphase nucleus and guided students to elaborate verbally the interpretation of its changes through mitosis as they described the photographs on the slides. She also established relationships between metaphase and anaphase with the corresponding cell-cycle checkpoint. As a summary, and also to reinforce the covered material on mitosis, a 2.47 minutes YouTube video was presented (https://www.youtube.com/watch?v=cvlpmmvB_m4). Juliette also described the stages of mitosis but hardly got responses of her students to her questions about the images. As the time session was running out, she chose not to use the video.

The student participation varied along the session. In Sylvia´s classroom, during the lecture segments of the session, most students showed engagement when dealing with low complexity subtopics: they listened, took notes, nodded their heads as recognition of their understanding, and asked questions to confirm their comprehension. As the cell-cycle regulation is a much complex subtopic; when it was introduced students seldom did anything but listen. Thus, the pacing of the class slowed down for students clearly struggled to recall the functions of proteins, a basic factual knowledge needed to incorporate new meanings into their prior knowledge i.e. to conceptualize cell-cycle regulation. The two activities within the collaborative groups were solved enthusiastically. In the final segment of the session students accepted the challenge of a third activity based on photographs of cells in different stages of mitosis. The video was gladly received; when asked by researchers after class, students commented it was a useful material to facilitate and enhance their learning.

Interestingly, researchers noticed differences in Juliette's classroom. Her students held less positive attitudes throughout the class; most of them seemed bored during the lecture segments and appeared reluctant to answer questions posed by Juliette. Students' interaction was poor or inexistent in some groups while solving the activities. Two students even left the classroom in the second half of the session as if they had decided that it wasn't worth staying.

In summary, both teachers acted alike during the session, promoting their students' understanding, carrying out a lecture and in-lecture activities format for their classes. Briefly, the main subtopics lectured by Sylvia and Juliette were the characterization of cell-cycle in animal cells, its regulation, and the cytological aspects of mitosis (Fig. 2).

4.3 Analysis of the teaching slides by the rubric

4.3.1 Descriptive overview

Sylvia's presentation consisted in 22 slides, including a first title slide. Sylvia employed slides containing solely images, only text and a combination of images + text (18, 1, and 1 slide, respectively). Her final slide was dedicated to a short video, downloaded from YouTube, depicting the cell division by mitosis. Juliette's presentation included a first title slide within a total of 22 slides. She also employed slides including only images, only text and a combination of images + text (19, 1 and 1 slide, respectively). She chose not to use the video due to time constraints.

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4.3.2 Assessment by the rubric

As it concerned our objective of documenting the participants' PCK, the assessment was focused on the content dimension. Detailed results are presented in the Appendix. Short descriptive outcomes related to the remaining dimensions were also elaborated and here presented.

Content dimension: all core contents (identified by a previous inquiry with expert colleagues) were addressed in both set of slides; subtopics were logically sequenced but each participant's elaboration differed in qualitative aspects. Connection and transition between concepts were achieved in both presentations by means of similar precise links. Sylvia's slides received a higher score on depth of content due to a more extended elaboration on cell-cycle regulation based on one of the learning goals of the class[1]. Her score was also higher for the variety of examples she presented to the students.

The scores for Sylvia's and Juliette's presentations were 17/18 points and 15/18 points for the content dimension, respectively (see Appendix for detailed results).

Organization and information dimensions: Sylvia's and Juliette's slides alike received the exemplary level.

Graphic aspects dimension: both presentations included a similar number of relevant slides to depict the topic. However, Juliette incorporated images from different sources –

[1] List the four stages of interphase, and describe the major events that occur during each stage in preparation for cell division.

List the checkpoints that regulate the progression of cells through the cell cycle and explain the mechanisms.

List the phases of mitosis in a eukaryotic cell, and discuss the major events that happen during each phase.

books and web pages– in the same slide; such diversity of representations was considered a potential cognitive overload that diminished their pedagogical value. She excluded the use of the video due to time constraints. Sylvia showed the video and revealed a creative use of images for she developed a short time extra in-lecture activity to summarize the phases of mitosis.

Textual aspects dimension: the two instructional materials had an appropriate simple design used as a mean to greater clarity; they both were exemplary on all indicators.

5. Discussion

In this study the PCK of two University teachers on mitosis was explored. The choice of this topic was based on its disciplinary centrality, and on that it is regularly taught in introductory biology courses. The tools employed were the Loughran et al. (2004) CoRe and PaP-eR, an analytical rubric, and semi-structured interviews.

The analyses of the results concerning the CoRes and PaP-eR through the Magnusson's et al. (1999) PCK components that framed our investigation led to the following appreciations.

Orientation toward science teaching. An orientation represents a general way of viewing of conceptualizing science teaching; it is described with respect to the goals of science teaching and the characteristics of the instruction (Magnusson et al. 1999). In reference to the goals of teaching this topic both teachers combined academic rigor and didactic orientations. Their classes were teacher-centered: they presented a body of factual knowledge by explanations and short discussions. Sylvia implicitly drove students to develop thinking processes whereas Juliette directed questions to students to mostly hold them accountable for knowing the scientific information on the topic.

Knowledge of science curriculum. This component of PCK consists of two categories: teachers' knowledge of the goals and objectives for students in the subject they are teaching and their knowledge of what students have learned previously and what they are expected

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to learn later on (Magnusson et al. 1999). Sylvia and Juliette are knowledgeable about the learning objectives for students in this course. They both started the session drawing the students' attention to them and throughout the lesson made clear connections to topics addressed in previous meetings such as DNA replication and cytoskeleton components. As veterinary medicine graduates, they were able to link mitosis to other courses, i.e. Pathology (Sylvia) and Basic Genetics (Juliette).

Knowledge of students' understanding of science. Two categories of knowledge are included in this third component: requirements for learning specific science concepts, and areas of science that students find difficult (Magnusson et al. 1999). Teaching experience accounts for Sylvia's and Juliette's awareness of students' difficulties on mitosis; they were able to list alternative conceptions, difficulties, and misunderstandings. Although they acknowledged the abstract nature of mitosis, they were not able to explicitly mention requirements for learning this topic.

Knowledge of assessment in science. There are two categories of knowledge included in this conceptualization: knowledge of the dimensions of science learning to assess and knowledge of the methods of assessments (Magnusson et al. 1999). Sylvia considered that oral quizzes were suitable for formative assessment in class; she believes individual and written summative evaluation should be implemented after the session. Juliette shares Sylvia's first idea. They both value the final course evaluation (multiple choice test on conceptual understanding) as the formal assessment but mentioned no alternatives to it.

Knowledge of instructional strategies. This component is comprised by two types of knowledge: knowledge of subject-specific strategies and knowledge of topic-specific strategies (representations and activities). Sylvia's emphasized on the students' involvement, and as observed in the actual class, she strongly intended her students to participate during the lecture. She mentioned activities dealing with factual knowledge of mitosis; some of them could be valued as topic-specific strategies e.g. simple mathematical calculations dealing with the number of chromosomes and chromatids in parental and daughter cells. Although varied, it is doubtful to conceive that these activities would

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actually engage students. Juliette stated that she has no knowledge of other teaching strategies than lecturing. During the session she intended to promote students' engagement with the topic by presenting examples related to veterinary medical practice.

Rubrics are widely employed as effective assessment tools in science teaching (Allen and Tanner, 2006); in the present work the innovative instrument by González et al. (2014) was applied to our participants' PowerPoint® presentations to assess their PCK and thus complement their CoRe and the PaP-eR. Two indicators –depth of content and data and/or examples inclusion– provided evidence of components of Sylvia's and Juliette's PCK related to the curriculum domain: knowledge of the learning goals of the session and knowledge of what students have learned previously and what they are expected to learn afterwards. Besides the differences detailed in the descriptive aspects, the analysis rendered other remarkable feature. The teaching sequence was prescriptive and encapsulated in the PowerPoint® slides provided by the course coordinator. However, as some modifications were available for teaching assistants to make; Sylvia's choice rested on the incorporation of slides concerning molecular aspects of cell-cycle regulation thus reinforcing the explanation of academic aspects of this troublesome scientific idea. Moreover, Sylvia included an additional slide about homologues chromosomes, another conflicting issue for students. On the other hand, Juliette included in her presentation supplementary images concerning the stages of mitosis. Sylvia's emphasis on the molecular aspects of cell-cycle regulation and conceptualization of chromosomes and Juliette's focusing on the cytological aspects of mitosis and cytokinesis revealed their knowledge of the students' understanding of specific science topics, specifically topics that students find difficult. Thus, the dimensions related to the slides as instructional materials showed that these teacher assistants chose different ways to represent and cover the content of the session, each highlighting those aspects of mitosis they valued the most relevant for their students and in coincidence of their responses to Co-Re question 2.

Few categories of the Magnusson et al. (1999) PCK components were identified in Sylvia's and Juliette's Co-Re, PaP-eR, and rubric outcomes consisting mainly in the transformation

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of disciplinary knowledge oriented to the presentation of content, and some factual conceptions about teaching procedures, curriculum and evaluation. At this point, to refine results from the assessments, it is interesting to introduce Talanquer's perspective (2004) on the PCK; this author argues that teachers' PCK must be sufficient to:

- Identify the main ideas associated with a topic.
- Recognize the students' probable conceptual difficulties and the impact on learning.
- Identify questions, problems or activities that require students to recognize and challenge their preconceptions.
- Select experiments, problems or projects that allow students to explore central ideas in the discipline.
- Build explanations, analogies or metaphors to facilitate understanding of abstract concepts.
- Design assessment activities that allow the application of learning in realistic and varied contexts.

Viewed in light of Talanquer's requirements (2004), we believe that both participants' PCK on mitosis can be characterized as incomplete, however not identical. The greatest concurrence was found in the identification of the main subtopics in the process of mitosis, and the difficulties in its teaching, focusing on some students' shortcomings. Sylvia's knowledge and beliefs informed by CoRe were aligned with her transmission-orientated teaching revealed in the PaP-eR. Nonetheless, Sylvia´s central ideas are more numerous and cover a wider range of subtopics, and throughout her class, she continually and systematically re-visited the session's goals. As evidenced by the rubric assessment and Pap-eR, in a format lecture she made room for a creative use of slides in an attempt to engage her students with the topic. Moreover, in previous study Sylvia's beliefs and ideas on the teaching of this topic revealed her reflection *on* action and reflection *in* action (González et al., 2014b). On the other hand, Juliette was aware of some critical aspects of teacher's PCK based, as Sylvia, on her classroom experience and her subject matter knowledge. She was at all times the driving force in the classroom, and although she explicitly connected mitosis and biological processes related to domestic animals, it failed to captivate her students' attention.

It resulted evident that although both teachers had been receptive towards the incorporation of in-lecture activities as proposed by the course coordinator; their limited knowledge about instructional and assessment strategies shaped their orientations towards science teaching and, mostly they taught as they had been taught.

We believe that the differences between Sylvia's and Juliette's PCK can be further explained by taking in consideration the filters and amplifiers included in the teacher professional knowledge bases model presented in Figure 1 (Carlson and Gess-Newsome, 2013). Filters and amplifiers comprise teachers' beliefs, orientations, prior knowledge and context; as a counterpart also students' beliefs, prior knowledge and behaviors are included as potential filters and amplifiers. Our participants share most of their formative disciplinary backgrounds and teaching experiences but, as noted in the PaP-eR, the climate of the classrooms differed: in Sylvia's classroom it was more relaxed and, on demand of her students, she devoted time to clarify erroneous or incomplete concepts whereas in Juliette's session, at certain moments, an air of tension seemed to prevail. The students' choices to attend to instruction or ignore it, embrace student-centered teaching practices or resist them as possible courses of action became crystal-clear in each classroom and, for Juliette, developed in a filter that diminished her good intentions and actions.

Numerous studies concerning effective teaching strategies for mitosis at diverse educative levels reflect its presence and relevance in science curriculums all over the world. However, being PCK a content-specific construct, investigations addressing this topic at universities are practically non-existent. The study reported here explored two University biology teachers' PCK on mitosis and is part of a bigger project; these results encourage us to carry on so knowledge gained from the research program would be built in novel contributions for high quality classroom practice.

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6. Conclusions and implications

- The CoRe and Pap-eR presented are autonomous because they illustrate how the PCK is evident by revealing specific aspects of the action in the classroom (Juliette) and reflection *on* action and reflection *in* action (Sylvia).
- The differences found in the teachers' PCK are consistent with the characteristics of this construct: PCK is specific to a topic, a teacher and a context.
- The analytical rubric provided pre-established performance criteria to make intelligible some aspects of the PCK components from the Magnusson and co-workers' theoretical framework adopted in this study. Its effectiveness and value as an assessment tool relied in its complementary character to other highly recognized survey instruments as the ReCo and PaP-eR.

We would like to close this article with a reflection on the assumption of the PCK as a continuum –from weak to strong– as it entails a second notion: PCK can be strengthened (Gess-Newsome, Carlson, Gardner and Taylor, 2010). The interaction of the components of PCK has been noted to be limited in research with novice teachers (González and Rossi, 2014a); a similar situation has been demonstrated in investigations with preservice teachers (Friedrichsen et al. 2009). Kind (2009) points that PCK remains unnoticed by many science teachers; for instance, as many of our fellow university teachers, Sylvia and Juliette, the two experienced teachers in the present work had never heard the term.

Our characterization of the participating teachers' PCK as incomplete indicates the strong need to pay special attention to the construction of PCK as a way of improving teacher professional knowledge (Kind, 2009; Loughran et al. 2012). Taking in consideration that the PCK of a teacher evolves throughout his professional practice (Olander and Olander, 2013) and, furthermore given the acknowledged role of reflection in the development of science teachers' PCK (Popovic and Antink, 2010), we highlight the relevance of including in-service training to enhance the professional development of university teachers. Moreover, in a context mostly limited to a traditional teacher-centered transmission of

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knowledge such as the university, and in line with several investigations that encourage the use of CoRes and PaP-eRs as an strategy to develop and support science teachers' PCK (Bertram, 2014), we strongly believe that may prompt university teachers to reflect meaningfully on their practice. The PCK development of teachers emerges as a strategy to re-orient the teaching of mitosis to modalities based on the construction of scaffoldings to facilitate students' learning.

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Appendix. Detailed results of the assessment on the PowerPoint® presentations.

	Sylvia's presentation	Juliette's presentation
Content		
Presence of core content	3 points	3 points
Logical sequencing	3 points	3 points
Connection between concepts	3 points	3 points
Transition between concepts	3 points	3 points
Depth of content	3 points	2 points
Data and/or example inclusion	2 point	1 point
Organization		
Introduction-body-conclusion format	3	3
Transition between slides	3	3
Internal coherence	3	3
Information		
Quantity	3	3
Quality (academic sources)	3	3
Pertinence of data	3	2
Graphic aspects		
Quality	3	1
Quantity	3	2
Relevance	3	3
Creative use	3	2
Textual aspects		
Grammar	3	3
Spelling	3	3
Terminology	3	3
Quality and extent of titles	3	3
Quality and extent of texts	3	3
Total score	**45 points**	**40 points**