

THE EFFECT OF TEACHER INSTRUCTIONS ON PRE-SERVICE TEACHER'S DEVELOPMENT OF PEDAGOGICAL CONTENT KNOWLEDGE

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Abstract

Trying to understand the knowledge base for teaching, the Pedagogical Content Knowledge (PCK) was proposed as the main teacher's knowledge. It amalgamates the specific knowledge and it is the difference between a teacher and a specialist. It can be both personal, deriving from practice, and canonical, which is cultural accumulation of what makes a good teacher. To acquire the last, preservice teachers (PSTE) take university classes, where theoretically their apprenticeship could be facilitated by the university teacher. Thus, it is important to understand how the university teacher best exerts his influence on PSTEs. In this paper, we show the impact of the university teacher's interventions in the development of PCK based on analysis of a course taught to chemistry PSTE. The research was conducted in a qualitative approach, in a case study strategy. The classes from a chemistry teacher's course from a federal university in São Paulo, Brazil were recorded for four months, to follow the development of the PCK. Qualitative forms of assessing the PCK, as CoRe, were used, and the tasks given by the teacher were collected to support the analysis. Our results show that the students' knowledge integration responds to teacher interventions, particularly when those were customised to each individual. When the intervention was made by means of written exercises the influence on PSTE was lower than orally and when made by peers even lower or null. Being so, teacher's interventions could be considered an INUS condition for the development of PCK in those students.

Key words: *knowledge integration, Pedagogical Content Knowledge, pre-service teacher, teacher formation.*

Introduction

In the history of education, several movements can be observed. All of them try to remediate the issues of its predecessor but, despite the change of educational habits, the necessity to prepare accordingly the teacher for this profession is undisputed. Since the 17th century, with Comenius and La Salle the need to form good teachers has been systematised (Comenius, 1907; Salm, 2007) but it is with the French Revolution that it became a governmental problem. The National Convention of 1794 created the first Normal School, initiating what is called as Traditional Education. The main objective was the consolidation of the emerging class, the bourgeoisie, that opposes the *Ancien Régime* (Old Regime) proposing a society in which people are supposedly free and succeed based on their own merits. To ensure it, all citizens ought to have the same educational opportunities (Reese, 2001). In fact, this educational model was not successful in integrating the marginalised people (allegedly, ignorant), leading to a general deception toward the scholar establishment.

New ideas about Education were then formulated, although they still supported the power of education, and accordingly with the main role occupied by the teacher. Nevertheless, the marginalised people began to be treated as the excluded, and not as the ignorant. Thus, in the late 19th century and early 20th (Cousinet, 1968), occurred the dawn of the progressive theory also known as *Éducation Nouvelle* (New School), which claimed that students must develop their own knowledge and the teacher should instigate and advise them. The focus of this theory moved from the teacher to the student (M. Depaepe, Simon, & Van Gorp, 2003; Reese, 2001). This educational movement has one great failure: it is expensive. Focus on students requires, for instance, smaller number of students *per* teacher, and more pedagogical resources are needed to promote a “natural development”. By this manner, this approach has been fully incorporated only for/by upper classes, however, the concepts of this new school were so impregnated in the common ideology, that lower class' teachers tried to apply the “educational zeitgeist”, but in huge classes and in lack of personal and material resources to instigate and promote a meaningful apprenticeship, it had counted against the education of the lower classes. The educational gap between the two worlds became even wider in a society where education was supposed to mitigate social differences.

North America Situation

In the late 19th century and until the middle of the 20th, North America had its own version of the Progressive Education. As researchers show (Davies, 2002; Labaree, 2007), this movement had not a singular identity, but can be basically divided into two perspectives the Pedagogical (PP) and Administrative (AP) Progressivism. The first had as founder John Dewey with great influence on teacher's beliefs and teacher's schools. The second had as paladin Edward Thorndike, and on contrary had larger impact on politicians: “whereas the former focused on teaching and learning in the classroom, the latter focused on governance and on the structure and purpose of the curriculum” (Labaree, 2005, p. 281).

As history shows the AP won this fight (Giroux & McLaren, 1989) by offering a model of School grounded in scientific means of achieving an objective (Schlossman, 1976). The movement ideas reshaped educational discourse in a way that diminished the intellectual aims of education in favour of a focus on “job training, social planning, political reform, social sorting, personality adjustment and social efficiency” (Labaree, 2007, p. 7), but the impact of AP has not been extended to the classroom, remaining mostly in the school administration and curriculum elaboration, and despite those efforts, the “school efficiency” policy did not improve the test results as were expected;

However, it expanded greatly the knowledge of the educational process, e.g. teacher education, teacher experience and teacher-pupil ratio (Hanushek, 1998).

It is notorious that teacher quality has a major impact on pupil achievement (F. Depaepe et al., 2015). Assuming that teachers must have a vast and solid array of skills, the importance of offering a good formation for PSTE can be easily recognised (Chamoso, Cáceres, & Azcárate, 2012). Also, it can be said that with the understanding of the educational process acquired in the administrative progressivism experience, it becomes possible to implement research-based policies in teacher education (Özçınar, 2015). In this perspective, the seminal work of Lee Shulman (Shulman, 1986) brings light to those “must have” abilities to “promote comprehension among students” (Chamoso et al., 2012).

The Teacher Education

There is no agreement in literature on which are the key elements for teaching (Barnhart & van Es, 2015); however, Grossman (1990, p. 5) highlights that “four general areas of teacher knowledge can be seen as the cornerstones” of Knowledge Base of Teaching (KBT): Subject Matter Knowledge, General Pedagogical Knowledge, Knowledge of Context and Pedagogical Content Knowledge (PCK). The importance of portraying KBT is that, once it is fully comprehended, it can be taught to prospective teacher (Grossman, 1990).

In his work, Shulman draws attention to the PCK, as being “of special interest because it identifies the distinctive bodies of knowledge for teaching” (Shulman, 1987, p. 8). This conception is already implicit in Dewey’s proposal of education (Grossman, 1990), and thus, accommodates some of the quarrel between AP and PP. It is also present in the work of Plato, Comenius (1907), later in Chevallard (Chevallard, 1982; Colomb, 1986) and Tardif (2014) which even supports the work done in the United States in the last 20 years as “development of a repertoire of knowledge base for teaching” (2014, p. 273).

Another aspect of the PCK is that it has in its nature, one that is acquired through formal education, thus the importance of the university teacher, and a personal one, which is gained by practice.

The last is gaining scholar attention, especially those where the PSTEs are put among students unfamiliar to them. Practical experiences are seen as one of the major sources for KBT (Shulman, 1987), specially for developing PCK (Park & Oliver, 2008). Kukk and Vahter (2012) assert that the practical experience is the most natural way to learn how to teach, and the consolidation of critical thinking and practical experience contributes to promote a self-development (Perrenoud, 1993) what Shulman calls wisdom of practice (Shulman, 1987). Nevertheless, the actual role of the university teacher has only been inferred, passing over the interaction between teacher’s instruction, student practice and PCK development.

It is well established that PSTEs rely on their own experiences in college to approach a subject or a classroom (Grossman, 1990), so the university teacher must play a major role in their formation. He must be able to create a prosperous environment, by arranging the curriculum and the educational units in such a way, that he can drive and inspire students to apprenticeship through self-development (Blašková, Blaško, & Kucharčíková, 2014), but does his presence in class exert a more powerful effect than the planning? Do the students’ peers also impact on the PCK development? Those questions remain unanswered.

In this research, the impact of a university teacher on his pupils is analysed by assessing the PCK of the students before and after instruction and also evaluating the structure and nature of the instruction. The collaboration of the students’ peers was also observed. It was adopted the Park and Oliver (2008) hexagonal model as it offers a construct for PCK and incorporates the reflection “in” and “on” practice as a main skill.

Theoretical Framework

As reported above, PCK construct has been used widely because it robustly describes teacher’s knowledge. It has been chosen among all PCK proposals, the one elaborated by Soonhye Park and J. Steve Oliver (2008), that was also employed by Toerien (2013), Barrett-Williams (2014) Borowski *et al.* (2012), and on other works by the method author (e.g. Park & Chen, 2012; Park, Jang, Chen, & Jung, 2010; Park & Suh, 2012). They are in line with Magnusson, Krajcik and Borko’s (1999) five aspects of PCK, with the addition of a sixth one, Teacher efficacy. This PCK construct consists on:

Orientations to Teaching Science: teacher's beliefs about purpose of teaching science, divided in nine orientations: process, academic rigor, didactic, conceptual change, activity-driven, discovery, project-based science, inquiry and guided inquiry.

Knowledge of Students' Understanding in Science: teachers must know student's main difficulties and what they know about a subject. This knowledge includes knowledge of students' conceptions of particular topics, learning difficulties, motivation and diversity in ability, learning style, interest, development level and needs.

Knowledge of Science Curriculum: this refers to teachers' knowledge about curricular materials, horizontal and vertical curricula and curricular saliency.

Knowledge of Instructional Strategies and Representations for Teaching Science: this is divided by authors in subject-specific strategies (general approaches for enacting science instructions) and topic-specific strategies (strategies for a particular concept).

Knowledge of Assessment of Science Learning: includes knowledge of the dimensions of science learning important to assess and knowledge of the methods by which that learning can be assessed.

Teacher efficacy: related to the individual perception of themselves, the belief on its own capacity for "execute their PCK effectively" (Park & Oliver, 2008).

Methodology of Research

This research was conducted in a qualitative approach, using the critical theory perspective, as proposed by Lincoln & Guba, 2000. As postulated by these authors, the ontology associated with this paradigm is historical realism¹, the epistemology is transactional and the methodology is dialogic and dialectical. Creswell (2007, 2009) points out that the critical paradigm perceives reality as a social construct in which actions must be made to overcome the systems of oppression. The research strategy adopted was case study (Denzin & Lincoln, 2000), and under the post-colonial rubric (Kincheloe & McLaren, 2000) the final aim of this research is to bring light to the mechanisms by which teachers build their knowledge, so that they can better exert their profession and contribute to social emancipation.

To achieve trustworthiness and accurate reflection of reality, the most important technique used is member checking (Cho & Trent, 2006), but in this research were also applied other means to assure it, as triangulation; debriefing sessions; peer scrutiny; examination of previous research findings; well-established methods from the literature; outlining the research design and its implementation; and prolonged engagement (Carcary, 2009; Shenton, 2004).

Research Design

It was chosen to analyse a fifteen-week chemistry teacher's course conducted in a federal university in São Paulo State, Brazil, whose main purpose was to discuss the planning of experimental classes using the Brazilian curriculum and, a Science, Technology, Society and Environment (STSE) approach. Such discipline counted with seven PSTEs that were divided by the professor in four groups (3 with 2, and 1 with 1 PSTEs), and they had one class of three hours' *ca* per week. The first three weeks were dedicated to theoretical appropriation and discussion of subjects related to the importance of planning a class ahead the laboratory classes; the next four, to experiment planning and tests; following four weeks, PSTEs practical lessons of 60 minutes to high school students; and the last four classes to analyse the given classes. The PSTE age varied from 20 to 29. In the group there were four males and three female PSTEs and most of them had none or few previous teaching experience. In this paper it is shown the

1 Also known as critical realism (Maxwell, 1992)

analysed data collected from one of the groups composed by two women who, by the time of the research, have already had around 1 year of previous experience in classroom. They belonged to upper middle class and lower middle class according to Graffar's model (Milani et al., 1983). All students and teachers signed an Informed Consent Form and the research was assessed by the ethics committee.

Data Collection

The data sources counted initially with non-participant classroom observations, instructional material and teacher's lesson plans, and videotaped recordings of the classes given by both teacher and PSTE (the last to high school students). After the initial analysis, using software Transana® searching for evidences of PCK and its components (Park & Oliver, 2008), the PSTE passed through a face-to-face semi-structured interview to elucidate the forehand data collection. Standardised questionnaires (Milani, Cortinovic, Rainisio, Fognini, & Marubini, 1983) were employed to verify the homogeneity of the stratum as well as the CoRe instrument to access the PCK (Loughran, Berry, & Mulhall, 2012; Loughran et al., 2001; Loughran, Mulhall, & Berry, 2004). The teacher's assessment tools as well as other documents (lab reports, homework, written assignments and posters for classroom presentations) were also obtained and were analysed by the software Altla.ti®.

Data Analysis

Teacher's knowledge is not a discrete knowledge, but a continuum and amalgamation of several ones, so it is important to determine the integration of all components and if they are put in a coherent way (Park & Chen, 2012). Therefore, in the PCK search, it was initially identified the moments in which PSTE presented indications of each of the six components (Orientations to Teaching Science –OTS, Knowledge of Students' Understanding in Science – KSU, Knowledge of Science Curriculum – KSU, Knowledge of Instructional Strategies and Representations for Teaching Science – KISR, Knowledge of Assessment of Science Learning – KAs, Teacher efficacy – TE), both in video recordings as well as in the written one. Those moments were coded correspondingly and then quantified in the following items: (A) the amount of each knowledge, (B) the proportion of each of them in the analysed document, (C) the number of times that each knowledge is associated with each other, (D) the amount of co-occurrence between pairs of knowledge (Rambaree, 2013), and (E) the co-occurrence index (c-index) (Brailas, 2014) as shown in the equation below. These data were used to form an adapted diagram presented by Park and Chen (2012) that is shown in Figure 1.

$$\frac{f_{AB}}{(f_A * f_B) - f_{AB}}$$

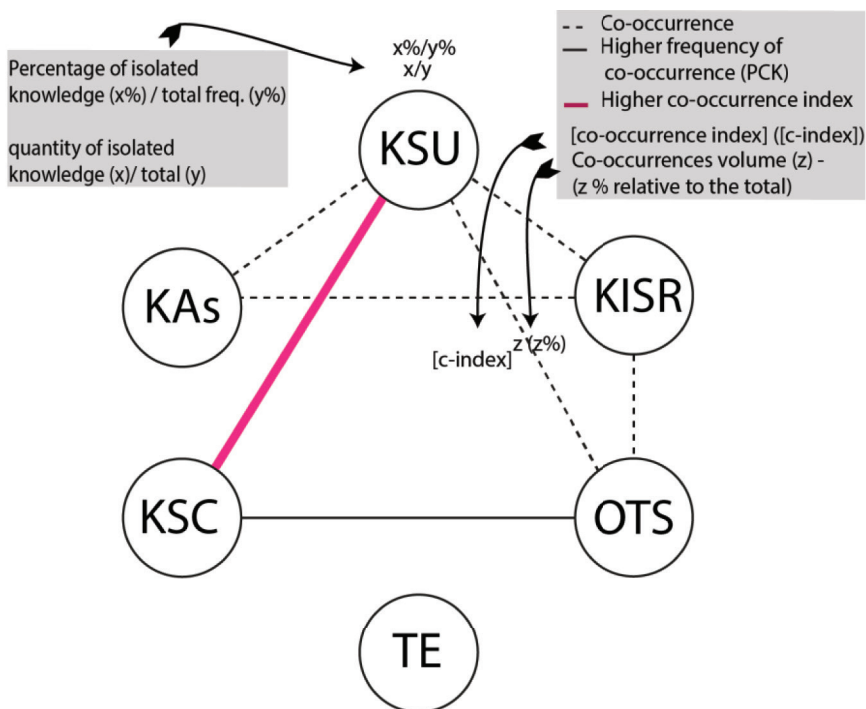


Figure 1: Scheme for the display of the knowledge frequency and integration.

Results of Research

The course was divided in four moments: (1) theoretical apprehension, when the teacher and the PSTE discussed bibliographies and theoretical concepts; (2) proposal and test of practical experiments, when PSTE raised and developed laboratory experiments, supported in discussions with the teacher; (3) application of PSTEs' experiments to high school students; and finally, (4) the replanning of the class and final discussion with the whole class, in order to improve the laboratory experiment. In each of these occasions, data were collected as shown in the upper part of Figure 2 (1, 2 & 4 had documental data collected and 3 & 4 had video recordings).

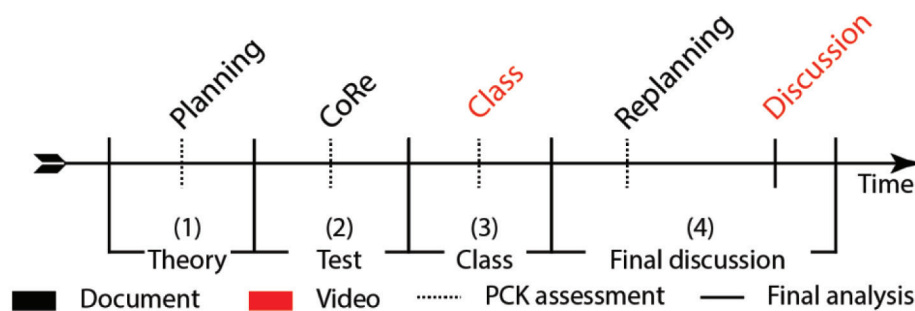


Figure 2: Timeline of the discipline and kinds of gathered data.

In the moments 1, 2 and 3, the PCK was assessed, whereas, in the fourth moment (replanning) the documents did not present a substantial difference from the first; thus, it was

analysed only the discussions made by the PSTE. For each of the first three moments, it was proposed a PCK map (as can be seen in Figure 3), inspired by the one proposed by Park & Chen (2012).

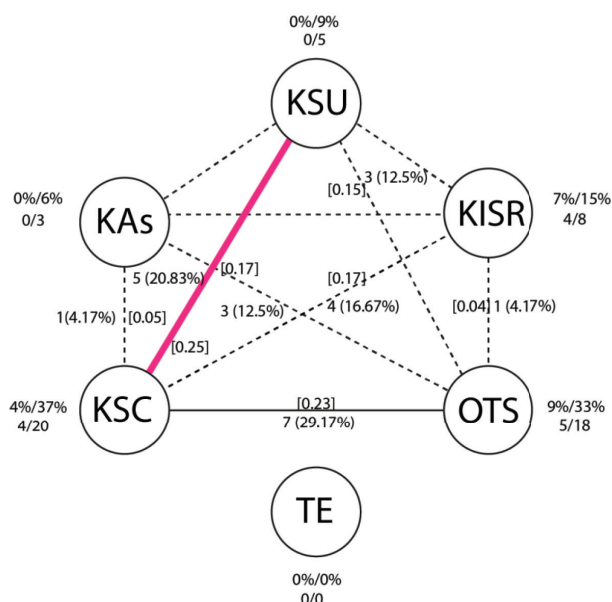


Figure 3: PCK map of the planning (moment 1) of the PSTE group analysed.

Figure 3, obtained from the planning for the class they would teach, shows that the most frequent knowledge is KSC, followed by OTS. Together they represent 70% of the PCK components expressed. Frequent as they are, it is easy to comprehend the largest amount of co-occurrence (PCK) (29.17%), but despite that, a stronger relation is found between KSC and KSU, expressed by the, not so large, c-index ²of 0.25, and 20.83% of co-occurrence. No co-occurrence was found between KSU and KAs or KISR, KAs show to be the smallest expressed, both isolated and associated with other knowledge, and TE was not found. Similar distribution can be observed in the PCK map made from the CoRe instrument shown in Figure 4, and in the PCK map obtained from the activities proposed by the teacher in moment 1 (Figure 5) very close one from the other with a high prevalence of KSC and OTS and low KAs and KSU.

In spite of those resemblances, a relation between KSU and KISR appears in the CoRe where there was none in the previous map, the KISR-OTS is highlighted, and the co-occurrence of KSC and OTS loses importance to the concerning KSC-KSU, which also doubles its c-index. When comparing to the PCK map from the activities, the analysed group shows in the plan a high correlation between KSC and KSU, a smaller correlation between KSC-KISR in the CoRe instrument and a small relevancy of KISR on both that contradicts the activities.

2 Covariance indicator.

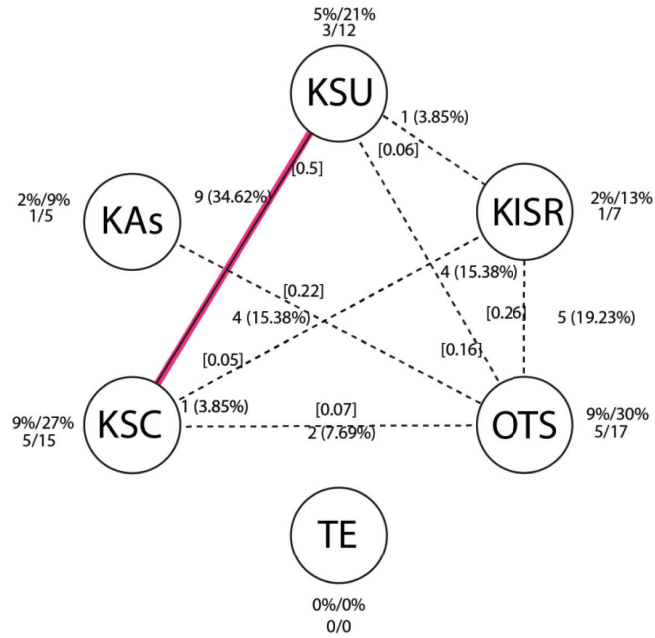


Figure 4: PCK map of the CoRe instrument of the PSTE group analysed.

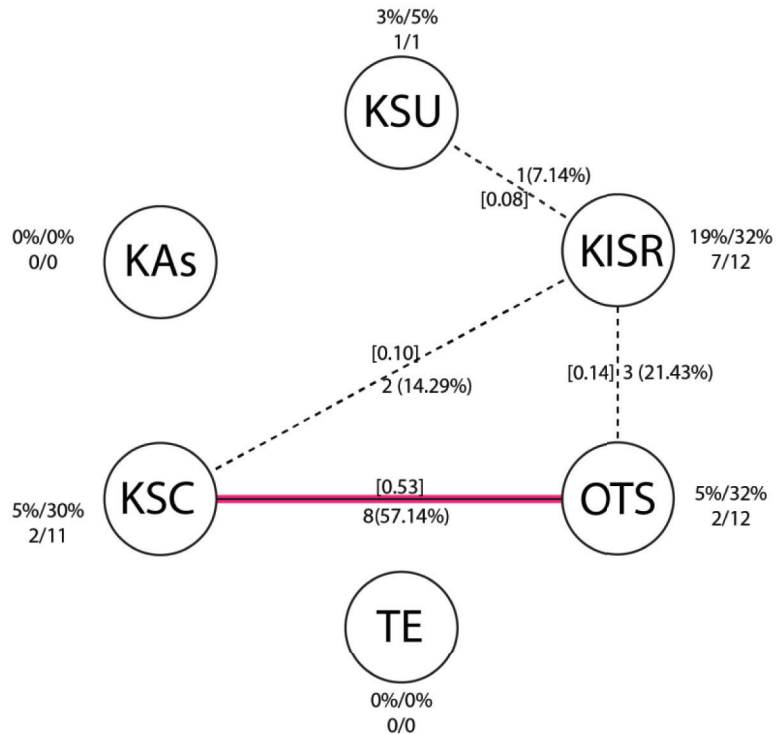


Figure 5: PCK map of the knowledge required in the activities proposed by the teacher in moments 1 and 2 in the PSTE group analysed.

In the third moment (applying the classes to the high schoolers), the PCK map (Figure 6) made from the class taught by the analysed group shows a more complex array. It was found 81 episodes in which the PCK components were shown, totalising 248 expressions and forming 307

correlations. Differently from the predecessors' moments, the most frequent correlation was KSU-OTS, and the larger c-index was found between KSC and OTS. The relevance of KSC, when comparing to the other components, is smaller in this moment, following the tendency of the previous maps. At the same time, KSU increases, contradicting the prevision of the planning.

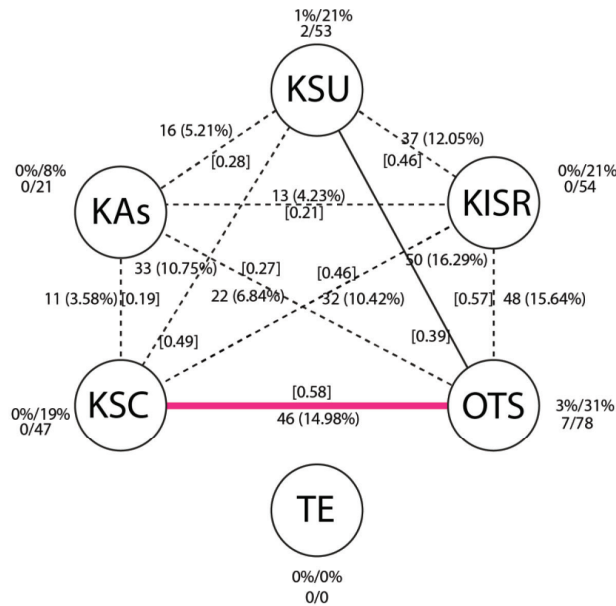


Figure 6: PCK map of the class given by the PSTE of the analysed group.

In all three moments, the KSC and OTS are the most appreciable knowledge, and the least is KAs, similarly to the knowledge portrayed in the objectives of the course (Figure 7). Those were assessed in the course syllabus and in all activities proposed, and they agree greatly with the PCK map from the activities (Figure 5).

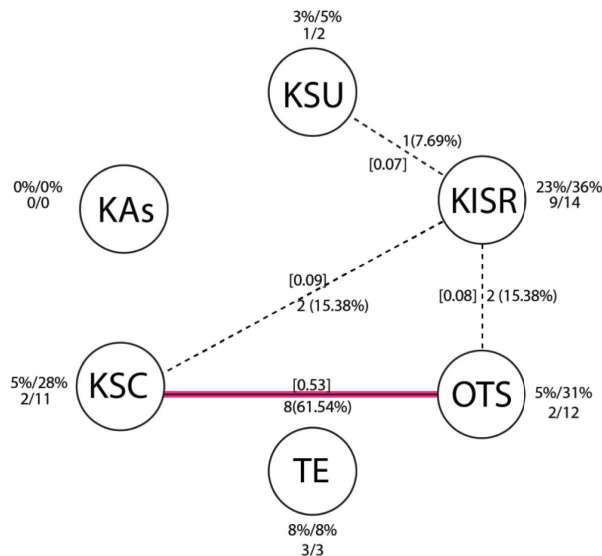


Figure 7: PCK map of the objectives of the course.

Just before the third moment, the PSTE presented their planning to the whole class (their peers), their teacher, as well as a guest teacher, who was invited just to give his expert insights. In such opportunity the comments made by the teacher and the peers (39 items) were mainly focused on the KSC (33%) (Figure 8), which corroborates the previous findings, but also in the KISR (31%).

Considering each *stratum* individually, the teachers' comments in KSU were almost as frequent as the KSC (23% to 30%), face that the peers' comments were less emphatic on this subject.

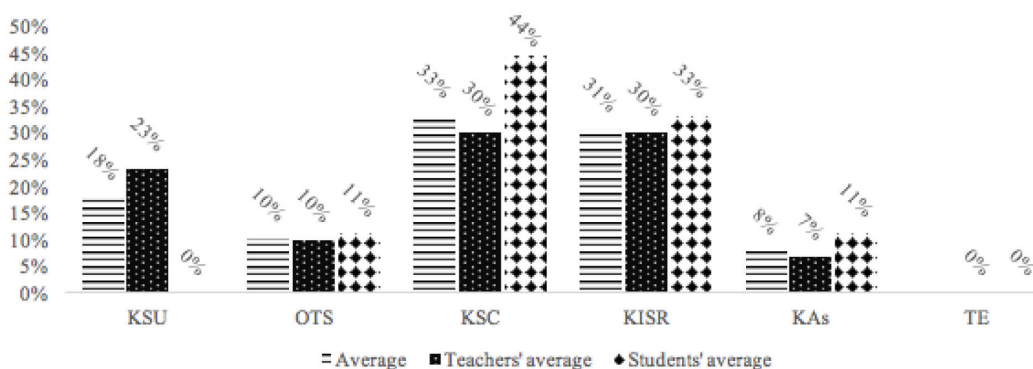


Figure 8: Knowledge proportions found in the comments made by the teacher and PSTE peers.

The PCK map of the comments made during such presentation (Figure 9) shows a complementary map to that expressed by the PSTE in the Plan and CoRe. It covers the relations the PSTE do not make (KSU-KISR, KSU-KAs and KAs-KSC) and emphasises some of the knowledge that they neglected (KISR).

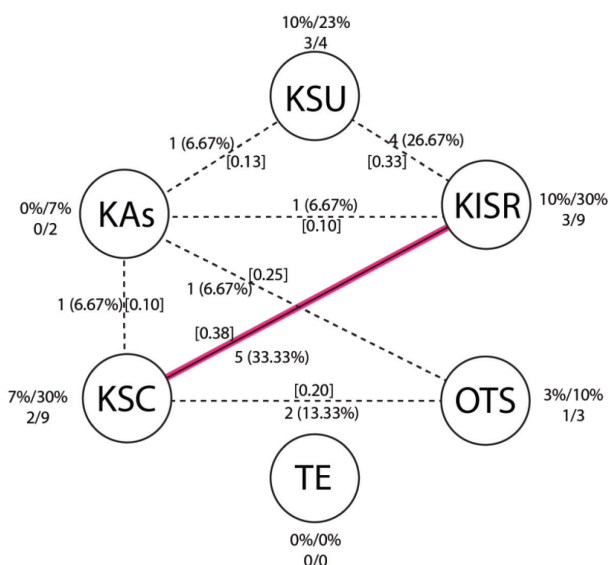


Figure 9: PCK map of the comments made by both teachers during the plan presentation.

One illustrative example can be seen in the following dialog recorded in class before moment 3:

Teacher 1 - This goes for all the groups. We have available here, in this lab, a large set of molecular models. Balls that assemble and disassemble.

PSTE – But the nicotine is quite large.....

Teacher 1- I do not know.... If you guys want, you can assemble one, or if one of the groups become interested.... I am saying it as a tool for everyone. To be aware of that we have it. I think we have ten kits. It is good to use, that is, if you think it is relevant....

Teacher 2- It is good to say that it exists. It is good disclose it, because sometimes people do not know or forget that it exists and this is a good tool to work on micro dimension.

Teacher 1- In the boys' group [referring to another group] I think it would be a good idea. I do not know

PSTE - Well..... We could take it in the next class and assemble it It's good because the students will be able to study, take a look at the molecule.

Initially, PSTE is reticent about using the model but at the end of this episode he points some qualities of this KISR. During the class, PSTE employed the model and the high school students interacted with it.

Discussion

As it can be seen from the results, the knowledge that was substantially recruited by the PSTEs in the first two maps were KSC and OTS, being used in such association to justify their Curricular saliency (Rollnick et al., 2008), while KAs & TE were barely noticed. The similarities and differences found between them appear to be coherent with the nature of the documents used to elaborate it. As there is no unifying agreement on how to measure PCK (Borowski *et al.*, 2011), we have employed an instrument that bestowed peer credibility, and that is used by several studies (Eames, Williams, Hume, & Lockley, 2011). The CoRe is an instrument designed to probe the complexity of PCK with all its components trying to capture the PCK by making subjects respond to eight questions about each of the main ideas of a chosen content (Loughran et al., 2001; Loughran et al., 2004; Garritz et al., 2013), being the most useful technique to capture and record directly teachers' PCK (Kind, 2009). It follows that it can capture all aspects from PCK bringing light to the hidden intents and objectives of the actions developed in the classroom, differently than the PCK from the plan. It was made under the recency effect (Jabine, Straf, & Tanur, 1984) of two activities proposed by the teacher that require, from the PSTE, the formulation of a plan for the class they were to teach, meaning the PCK components shown are likely to be the ones requested in those tasks, and clarify the increase in KSU. This may indicate an influence of the teacher in the abilities expressed by the PSTE, as they spend time reflecting how they would express that knowledge in a real class. That hypothesis is strengthened by the map from the activities, which presents a heavy emphasis on KSC and OTS alongside with a strong relation between them and a lack of attention to KAs and KSU.

The high use of KSC and its association with KSU is very important for this first step of a class (planning) and is supported by literature. Freire and Fernandez (2013) pointed out that the planning phase of a discipline requires a high investment of KSC, as it is “fundamental for the articulation of the different knowledge” (p. 5), but several studies indicate that planning a class requires an intimate articulation between knowledge of the subject, the goals and the way to achieve it (Martin, 1994; Zahorik, 1970), which is not seen in this case. Other study even points that the great difference between experienced and novice teachers is exactly the ability to plan (Leinhardt, 1989).

It also can be perceived that some characteristics endure throughout the two-first students maps: a high correlation between KSC and KSU and a small relevancy of KISR on both, contradicts the activities and a global PCK analysis from the CoRe, which indicates a latent refractory knowledge array in PSTEs' group.

The complex array presented in the class demonstrates that the praxis is, in fact, much more complex than the plan. In addition, the decreasing on relevance of KSC and thereby co-occurrence with KSU can be justified by its demand be higher when preparing for a class. With regard to the raise in KSU, it is possible that this knowledge is not well consolidated, so it is not clearly expressed in the planning and in the CoRe, although intuitively the PSTE realise its importance and used it in practice. Park and Chen affirm that the KBT of PSTE is not only shorter but less structured than the experienced teacher (2012). In a similar conclusion, Aydin & Boz argue “to be a successful teacher, the integration among the components of PCK is essential” (2013, p.615).

When comparing the first maps to the map from the objective tendencies appears, as the emphasis laid on KSC ant OTS. The interconnection between the goals and the proposed activities was previously studied (Gastaldo & Leal, 2015) and had shown that, in fact, there is a correlation and, moreover, it is possible to perceive a linear growth in the cognitive demand. That allows to affirm an intentionality and a coherence in those kinds of knowledge from the objective and activities, being the ones the teacher perceives as the most important in planning. So, those kinds of knowledge are purposefully developed through the educational experience. Despite that, it is hard to attribute some changes only to the lessons proposed over the discipline as, for example the doubling of KSU and the increase of KISR. A deeper understanding of the role of the teacher in the development of PSTE’s knowledge can be gained observing the comments made by the teacher in the class, previously to moment 3.

As highlighted before, up front to moment 3 they presented the plan to their peers, the teacher and the invited teacher. In such opportunity the PSTEs were told to improve their KISR, as can be noticed in the excerpt from the class, marking a temporal precedence with the presentation of the behaviour. It is important to regard the differences between the averages of the comments made by the peers and by the teachers. The teachers focused their comments on KSU (23%), KSC (30%) and for the first time in KISR (30%) with PSTE increasing of KISR (from 13% to 21%) expressions and maintaining a considerable KSC (19%) and KSU (21%), alongside with the great amount of comments made by the peers relating to KSC (44%) with PSTE decreasing KSC (from 27% to 19%). The distinction between *strata* is important to highlight this phenomenon and infer the impact made only by the teachers’ influence.

It is easier to attribute the change in the PCK map of the class taught by the PSTE to the educational experience when looking at the PCK map of the comments made during such presentation (Figure 9). It is more complex than the previous maps from the teacher and seems to relate specifically to this group in the knowledge they appear to lack (relation between KSU & KISR, KSU & KAs and KAs & KSC; and also increases the proportion of KISR). Nevertheless, KAs and TE are still undervalued, giving a probable explanation for the same undervaluation in the maps made from the PSTE. The excerpt from that moment presents a vivid and explicit demonstration of teacher’s interference, made directly to a deficiency he perceives, and even to those groups that are not directly involved in the conversation. Mirzaei *et al.* claim that “the learning process for teachers must be about their practice, must be built on experiences derived from their practice” (p. 641). In this presented case the teacher discusses the PSTEs’ practices alongside with them helping to develop a critic sense over the teaching practice. There is a consensus about the importance of teachers’ availability to critically analyse their own practice (Barnhart & van Es, 2015). Reflections about the educational process allow to develop teacher’s reasoning about how to employ certain instructional strategies (Mirzaei *et al.*, 2014), which is exactly what the teachers do in the excerpt by showing a way to introduce a curricular aspect (chemical structure) through a strategy (molecular model) agreeing to Soisangworn and Wongwanich (2014), when they define reflective teaching as the reflexive application of knowledge into practice. But, although the critic reflection is a central step in the educational process, the analytic skill is not easily acquired (Barnhart & van Es, 2015), and it

is important that university teachers promote that development in their students (Mirzaei et al., 2014), as can be seen here. Similar or more implicit actions permeate the course in a way that was intended by the teacher and is important to be so, as it is the core of the educational praxis and he is privileged in this process (Kukk & Vahter, 2012).

Those data point to the affirmation that the teacher can modify the PSTEs' practice, but, to establish a causal relation between the educational process and the development of the described knowledge is not a simple task. In the classical vision of causation, Hume (1739) defines that for two phenomena to be in a causal relation, there are 8 conditions, among them: correlation, covariation, temporal precedence of the cause, and that no other phenomenon causes the effect. The case presented here has clearly the first three of them, not being possible to assure the last one. To discard a change through any other phenomena, Fisher introduced, in 1937, the notion of randomisation (Fisher, 1937), in which the subjects are randomly divided in two groups (test and control). However, the use of randomisation in social sciences has been questioned, due to the difficulties to achieve a perfect control of the variables; the ethical questions of denying the possibly best intervention to a control group; and finally by the influence caused by the artificial randomisation (Pearl, 2000, 2009). Otherwise, Mackie (1965) states that "what we often speak of as a cause is a condition" (p.245) and, in this way, proposes an alternative to the cause construct, the INUS condition "an insufficient but necessary part of a condition which is itself unnecessary but sufficient for the result" (p. 245). In that manner, the teacher intervention configures an INUS condition for the development of the PCK in the PSTE, which empirically demonstrated what the literature (Grossman, 1990; Shulman, 1987) brings as positive impact of formation of the development of the PCK. Nevertheless, our results reveal a deeper aspect of the formation by bringing the actions of the teachers to the focus and showing how they exert their influence.

Conclusions

This research aimed to determine the impact of a university teacher on PSTEs' development of the PCK and its components and if/how they change the integration among them. The methodology proposed was able to characterise the PCK from them through the course, and has shown that they put a great deal of importance on the KSC and in the OTS, but the strongest relation was found to be between the first and KSU. It was also characterised the teacher's knowledge demand by means of the activities and syllabus objectives. It was demonstrated that the PCK of the PSTE changed along the course, becoming gradually more complex by the teacher's guiding. Such modification was more abrupt when the teacher's interference was made orally and customised to the analysed PSTE group, as standardised written instructions and exercises did not have such impact, and specifically when made by the teacher as the impact of the peers was less relevant. The university teacher actively changed the way the PSTE viewed the class planning by helping them to better understand the importance of reflecting in their planning and doing so developing their own knowledge and setting new strategies. Teacher's interventions had a positive correlation, covariation and temporal precedence to be an INUS condition as it was able to modify the PSTE knowledge in a non-redundant but no exclusive way. This is an important result as it shows different ways by which PSTEs are influenced, and especially those that exert more impact. Despite the lack of generalisation power, our results reinforce the substantive role of the teacher in the classroom as an active and critic producer of knowledge. Further research should determine if this phenomenon can be reproduced in other circumstances.

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