# CAPÍTULO III: SCIENCE TEACHING STRATEGIES DEVELOPED IN AN ONLINE COMMUNITY OF PRACTICE

## A CASE STUDY

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(aceite para publicação)

*The International Journal of Web Based Communities*.

# CAPÍTULO III: SCIENCE TEACHING STRATEGIES DEVELOPED IN AN ONLINE COMMUNITY OF PRACTICE - A CASE STUDY

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**Background**: Communities of practice (CoP) have been presented in the literature as potential promoters of the improvement of teaching strategies. However, there is scarce empirical evidence of that impact, namely in science education. **Purpose**: This study aims to present empiric evidence supporting the potential of online CoPs, involving teachers and researchers, for the development of effective science teaching practices – considering the literature on science education (SE) regarding strategies that can effectively promote pupils' learning. **Sample, design and methods**: The authors conducted a single case study: a curricular module developed by a collaborative group of five teachers and three researchers, which formed a CoP under the Portuguese project IPEC[1]. The CoP members interacted mainly through online communication tools; therefore, content analysis of the developed lesson plan, and associated teaching resources, was complemented with evidence from online interactions, as well as documents produced by the CoP as dissemination papers. **Results and conclusions**: The study showed that the CoP developed a field trip combining diversified teaching strategies, such as learning of contextualized phenomenon, small work group or questioning, referred in the reviewed literature as effective science teaching strategies. The results also point to the evolution of the teachers' practices during their participation in this CoP. Hence, it provides empirical evidence that supports that online CoP of teachers and researchers can promote the improvement of science teaching practices. It also gives a glimpse of possible factors that can contribute to that improvement, which require further empirical study.

**Keywords**: teaching strategies, science education, online community of practice, teachers' professional development

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[1] The IPEC project 'Investigação e práticas lectivas em Educação em Ciência: Dinâmicas de interacção' was sponsored by the Portuguese Foundation for Science and Technology (POCI/CED/58825/2004).

## ***3.1. Introduction***

The teachers' practices seem to be one of the most powerful influences on students' achievement (Guskey & Sparks, 2002; Hattie & Anderman, 2013). Hence, the **identified problematic** is the need of teacher professional development (TPD) with positive impact on practices and, thus, the increasing interest of the international academic community (e.g., Avalos, 2011; Borko, 2004; Dede *et al.*, 2009; Holmes, 2013; Tytler *et al.*, 2011). One particular way of TPD, and consequently of promoting the quality of teaching practices, is the use of different social configurations involving teachers. This includes 'networks' (Bacigalupo & Cachia, 2011), 'communities of inquiry' (Holmes, 2013), 'professional learning communities' (Vescio, Ross, & Adams, 2008) and 'CoP'[2] (Santos, 2012). Accordingly to the literature, some features that seem to contribute to TPD are the fact that teachers' social configurations can ***i)*** reduce teachers isolation and promote their reflexivity, reasoning and self-confidence (Avalos, 2011; Holmes, 2013); ***ii)*** allow self-assessment of the teaching views and practices (Barab, MaKinster, & Scheckler, 2004); ***iii)*** promote the learning of theory and practice (*idem*); ***iv)*** enable the development of a work centred on the teachers' practices and needs (Dede *et al.*, 2009; Tytler *et al.*, 2011); ***v)*** enhance innovative and theoretically updated experiences (Schlager, Fusco, & Schank, 2002), and ***vii)*** be long-term experiences, which are more effective than short-term programmes of TPD (Avalos, 2011).

In the area of interest of this paper, some **studies of online CoPs involving science teachers** (e.g., Barab, MaKinster, & Scheckler, 2004; Cooper, Grover, & Simon, 2014; Fazio, 2009; Schlager, Fusco, & Schank, 2002; Vavasseur & MacGregor, 2008) were identified. However, the published research often focuses on the description of the creation/sustainability of the community and its advantages to TPD, without documenting the actual changes on teaching practices. Therefore, there seems to be a lack of empirical evidence of the impact of CoP on the practices of teachers, particularly when online communication tools are explored (Dede *et al.*, 2009; Lai *et al.*, 2006; Vescio, Ross, & Adams, 2008), in science education (SE) contexts and with collaboration between teachers and researchers (L. Marques *et al.*, 2008).

[2] The concept of CoP adopted in this contribution was explored before (Marques, Loureiro, & Marques, accepted) and can be summarized as follows: "A community of practice is a unique combination of three fundamental elements: a **domain** of knowledge, which defines a set of issues; a **community** of people who care about this domain; and the shared **practice** that they are developing to be effective in their domain." (Wenger, McDermott & Snyder, 2002, p.27, emphasis in original).

In previous studies, this paper's authors documented the innovative nature of the science teaching practices (Marques, Loureiro, & Marques, accepted; Marques, Loureiro, & Marques, 2011) developed by a group of teachers and researchers. They formed an online CoP (Marques, 2008) under a Portuguese research project, the IPEC[1]. This project aimed to promote the collaboration between teachers and researchers in the context of SE, contributing to overcome the acknowledged gap between these two communities (Goos, 2008; Loureiro *et al.*, 2006; Sabelli & Dede, 2001; Vanderlinde & Braak, 2010).

In line with the above mentioned, **this study aims** to contribute to present empiric evidence supporting the potential of online CoPs, involving teachers and researchers, to improve teaching practices, in SE contexts. We focus on an observable part of science teaching practices, the teaching strategies, developed by a collaborative group of the project IPEC. Consequently, this study **research questions** are the following:

(1) 'What science teaching strategies were developed by an online CoP of teachers and researchers, created within the project IPEC?' and

(2) 'Are the teaching strategies developed consistent with the indicators of SE's literature, regarding teaching strategies that can effectively promote pupils' learning?'

**Methodologically**, this is a qualitative and exploratory single case study (Yin, 2009), being the case the science teaching strategies developed by an online CoP involving teachers and researchers in SE.

The following sections provide: ***i)*** a literature review aiming to supported the development of a framework for content analysis of science teaching strategies; ***ii)*** the description and justification of the methodological options of this study, and well as its context and participants; ***iii)*** a presentation of the studied CoP's teaching strategies and discussion of their consistency regarding SE literature indicators; and ***iv)*** final considerations concerning this study's contributions and limitations.

## ***3.2. Teaching strategies in Science Education***

This brief review of the literature focuses on one aspect of the science teaching practice that teachers' CoP might contribute to improve, i.e., the teaching strategies. Thus, we sought to ***i)*** clarify what do we mean by teaching strategy; ***ii)*** review meta-analysis of research on science teaching strategies with positive impact on student's learning; and ***iii)*** synthesise studies that also included teaching strategies that did not reveal such evidence, but which might contribute to the development of a data analysis' framework.

The classroom teaching practice of promoting students' learning can have several designations in the SE literature: 'teaching activity'[3] (De Pro Bueno, 1999), 'activity' (Furtak *et al.*, 2012), 'didactic strategy' (Hus & Grmek, 2011), 'teaching strategy' (Minner, Levy, & Century, 2010; Schroeder *et al.*, 2007; Wise, 1996; Wise & Okey, 1983), and 'instructional strategy' (Marzano, Gaddy, & Dean, 2000; Taraban *et al.*, 2007; Tate, 2003), among others. We prefer the term '**teaching strategy**' as it seems to be used by several authors and also seems to imply the idea of purpose in what is done in the interaction student-teachers-learning resources. In this line of thought, in Portugal, e.g., Vieira and Vieira (2005, p. 16) define teaching strategy as a 'set of teacher or student actions, oriented to favour the development of certain aimed learning competences'[4]. Gaspar and Roldão (2007, p. 89) characterize it as an 'intentional action oriented towards a learning goal based in the learner and mediated by the action/interaction supplied by the teaching'[5]. Leite (2010, p. 24) presents it as a 'choice of a technique, a way of organising the pupils, activity or sequence of activities, a set of framed tasks (...) aiming a particular purpose and considering a specific population in a given context'[6]. Summing-up, a teaching strategy seems to require a clear expression of the aimed educational goal(s) and a detailed forethought of the process (which actions are performed by which protagonists?) and resources required to their(s) pursuit.

For more than three decades, research in SE has sought to distinguish different types of science teaching strategies (De Pro Bueno, 1999; Herbert *et al.*, 2003; Hus & Grmek, 2011; Tate, 2003; Vieira & Vieira, 2005) and conducted meta-analysis to identify and/or characterise those with greater positive impact on pupil's learning (Furtak *et al.*, 2012; Marzano, Gaddy, & Dean, 2000; Schroeder *et al.*, 2007; Wise, 1996; Wise & Okey, 1983). We agree with Marzano and colleagues (2000) and Schroeder and colleagues (2007) regarding the difficulties of defining a category system for teaching strategies. Actually, we found a **high dispersion of analysis frameworks**, especially when we consider the number and level of detail of the proposed categories. This makes it difficult to understand and compare different proposals. E.g., most studies focus on action categories, as the questioning of the students (De Pro Bueno, 1999; Herbert *et al.*, 2003; Schroeder *et al.*, 2007; Tate, 2003; Vieira & Vieira, 2005) or 'to generate and test

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[3] In the original: "actividad de enseñanza" (Bueno, 1999).

[4] In the original: "conjunto de acções do professor ou do aluno orientadas para favorecer o desenvolvimento de determinadas competências de aprendizagem que se têm em vista" (Vieira & Vieira, 2005, p.16).

[5] In the original: "acção intencional orientada para um objectivo de aprendizagem sedeado no aprendente, e mediado pela acção/interacção proporcionada pelo ensino" (Gaspar & Roldão, 2007, p.89).

[6] In the original: "escolha de uma técnica, de uma forma de organização dos alunos, de uma actividade ou sequência de actividades, de um conjunto de tarefas enquadradas (...), com vista a uma determinada finalidade e tendo em conta uma população específica, num dado contexto" (Leite, 2010, p.24).

hypotheses' (Marzano, Gaddy, & Dean, 2000). However, Furtak and colleagues (2012) distinguish the cognitive dimension (which includes the procedural, epistemic, conceptual and social facets) from the guidance degree (teacher or student-led) of inquiry-based teaching. Other authors, as Hus and Grmek (2011), base their analysis on the type of lesson. The level of detail of characterization of the teaching strategies is also very variable. E.g., Vieira and Vieira (2005) propose a system of strategies so detailed that they even distinguish debate from discussion. Finally, Tate (2003) presents a set of teaching strategies which she claims to be effective, according to her analysis of research, but does not characterise them, focusing only on the arguments in favour of each type of strategy.

Despite the above-outlined dispersion, some **points of similarity** were found in different proposals of teaching strategies categories. E.g., the studies of Okey and Wise (1983), Wise (1996) and Schroeder and colleagues (2007) are an evolution of a system of categories of science teaching strategies with higher impact on students learning. They have been frequently cited in the literature throughout the years. For instance, Minner and colleagues (2010) reported obtaining similar results to those of Schroeder and colleagues. Additionally, all these studies advocate the adoption of inquiry teaching practices, particularly those promoting students' active thinking and deduction from data. Another intersection point of these studies is the fact that Johnson and colleagues (2012) built a protocol to identify components of effective science instruction partially based on Schroeder and colleagues' work. Furthermore, different systems of categories from different authors present some similar categories, such as the strategies involving questioning the class, named 'questioning' (Schroeder *et al.*, 2007), 'intentional questioning of the teacher' (Vieira & Vieira, 2005) or 'teacher's lecture, interacting with the class' (De Pro Bueno, 1999).

From the reviewed studies the **inquiry-based teaching** emerges as promoter of student's learning (Furtak *et al.*, 2012; Johnson *et al.*, 2012; Minner *et al.*, 2010; Schroeder *et al.*, 2007; Wise, 1996; Wise & Okey, 1983). Yet, there seems to exist no consensus regarding the inquiry-based components of SE. E.g., Minner and colleagues (2010) consider inquiry requires an investigation cycle that comprises generating questions, designing experiments, collecting data, drawing conclusions and communicating findings. On the other hand, Meyer and Avery (2010) focus on two problems that must be addressed in the inquiry-based teaching: the lack of contextual background of students entering the scientific investigation and the level of difficulty of the challenge proposed. In this line, Furtak and colleagues (2012) reported too open tasks as hinderers of student's achievements.

Considering the above presented analysis, we produced a list of **teaching strategies with reported high positive impact on pupils' learning**. We took the effect-sizes presented in the studies of Marzano and colleagues (2000) and Schroeder and colleagues (2007) into account, being the first strategy the one with the greatest reported potential in promoting students' learning in SE:

(1) enhanced context strategies (Johnson *et al.*, 2012; Schroeder *et al.*, 2007; Wise, 1996), which contextualizes the learning in real phenomena or in students' interests (Tate, 2003), considers the activation of their previous knowledge (Furtak *et al.*, 2012; Marzano, Gaddy, & Dean, 2000), and recommends conducting field trips (Tate, 2003);

(2) collaborative or group work (Furtak *et al.*, 2012; Johnson *et al.*, 2012; Minner *et al.*, 2010; Schroeder *et al.*, 2007, among others);

(3) non-linguistic representations (Marzano, Gaddy, & Dean, 2000), which may include drawing, writing, construction of graphic organizers, use of visuals and of movement (Tate, 2003), in other words, multimodal representations;

(4) questioning strategies (Johnson *et al.*, 2012; Schroeder *et al.*, 2007; Vieira & Vieira, 2005);

(5) laboratory inquiry strategies, in which students answer scientific research questions by analysing data (Johnson *et al.*, 2012; Schroeder *et al.*, 2007; Wise, 1996; Wise & Okey, 1983);

(6) assessment strategies (Schroeder *et al.*, 2007), which include providing feedback (Furtak *et al.*, 2012; Marzano, Gaddy, & Dean, 2000);

(7) manipulation strategies and instructional technology strategies (Schroeder *et al.*, 2007; Tate, 2003; Wise, 1996; Wise & Okey, 1983), which include practical engagement with science phenomena (Furtak *et al.*, 2012; Minner *et al.*, 2010); and

(8) debate/discussion (De Pro Bueno, 1999; Furtak *et al.*, 2012; Tate, 2003; Vieira & Vieira, 2005), highlighting the relevance of the argumentation in learning (Meyer & Avery, 2010).

Briefly, the above presented literature review allowed us to establish a theoretical framework to guide the analysis of the data collected during this case study. This framework will be described and justified in the following section, as well as our methodological options.

## ***3.3. Methodology***

Regarding the research method, the lack of similar studies in the literature and the type of research questions presented in the Introduction section justify the option of an exploratory study (Yin, 2009). Also, the contemporary of the phenomenon, within a real-life context and with no researcher control over events contributes to justify the choice of a case study (*idem*). This allows a deeper understanding of the selected case: the science teaching strategies developed by a collaborative group of the project IPEC.

### *3.3.1. Study's context and participants*

This section presents the context of this study, the project IPEC, which promoted a Portuguese community from May 2006 to September 2008. Its researchers, specialists in SE, had worked together previously and invited science teachers they knew from other contexts to get involved. Through negotiation of interests, IPEC's members formed four groups (G1 to G4) and collaboratively designed, implemented and evaluated curriculum modules related to sustainability. They interacted through an online platform and in face--to-face meetings. A group, G2, was selected based on the following criteria: it was a community; it interacted mainly through online asynchronous communication tools; it was recognised as a CoP. For further details on the selection process, see Marques (2008) and L. Marques and colleagues (2008). For further information on G2's use of the online platform and development of related skills, see M. Marques and colleagues (2008). Furthermore, the analysis of the dynamics that led to the development of the teaching strategies analysed in this contribution is presented in Marques, Loureiro and Marques (submitted).

Five teachers, referred in this paper as TA to TE (four specialists in 'biology and geology' and one in 'physics and chemistry'), and three researchers in SE (two male and one female) formed G2. The teachers had a long teaching experience (11 to 21 years), most with post-graduation in SE and all of them used information and communication technologies (ICT), mainly word processor, Internet browser and e-mail. None of them had experience using ICT in distance learning. All the researchers had a PhD degree and more than 20 years of research experience. Two used ICT tools as the teachers did and one was an expert in educational technology, therefore, used ICT with several objectives, including teaching.

At the beginning of the IPEC project, the involved teachers reported distinct perspectives of education, with a greater tendency for a transmissive teaching (focus on instruction, with content and teacher-centred approaches). However, some stated they explored interdisciplinary and Science-Technology-Society approaches, as well as they conducted practical activities such as experimental work and field trips. For further details on the project IPEC and G2's work, see L. Marques and colleagues (2008) and Marques (2008).

### *3.3.2. Data Collection*

The used data collection techniques were documentary data (Quivy & Campenhoudt, 1998) and observation (mediated by IPEC's platform). Data was collected from the final individual reports of G2's teachers, which included their reflections about the project, as well as their lesson plan and teaching resources developed. We also collected the records of the G2's interaction in an online platform that supported the project, hence, 625 messages and their attached documents (total of 148), posted in four group forums. Additionally, the minutes of the group's face-to-face meetings and documents of divulgation of their work outside their community (Fernandes *et al.*, 2009; Morgado *et al.*, 2008; Pinto *et al.*, 2009) were also consulted. The observation period was from September 2006 to June 2008, when G2 planned, enacted, assessed, reformulated and adapted, re-enacted and re-assessed their curricular module.

The data collected from several sources, as described above, was submitted to triangulation (Given, 2008). This was done in order to cross verify the information collected regarding G2's science teaching strategies and, hence, to increase the validity of findings. Additionally, nearly all G2's teachers reviewed the triangulated data to comment on it.

### *3.3.3. Data Analysis*

The authors sought to minimize the subjectivity inherent to the interpretation of the data collected through the development of a data analysis framework and its use to perform content analysis (Bardin, 1991).

The analysis framework was drawn from literature and addresses the notion of teaching strategy adopted (based on Gaspar & Roldão, 2007; Leite, 2010; Vieira & Vieira, 2005). Thus, aligned with De Pro Bueno (1999), we sought the analysis framework to include three distinct dimensions of teaching strategies: specific actions, such as participating in a debate or manipulating instruments; the protagonist of those actions (teacher, students in small group or other option); and resources used during those actions (see tables 1, 2 and 3 in the next section).

The above referred framework was used to perform a content analysis (Bardin, 1991) of the triangulated data. Quantitative content analysis has been pointed in the literature as helpful in answering ‘what’ questions (Given, 2008), as in this study. During the coding process, the teaching strategies categories were not considered exclusive because some actions foreseen in the lesson plans could be included in more than one category. For example, the action ‘The teacher shows the class a PowerPoint presentation with pictures that highlighted some of the characteristic features of the Quarry Feifil’ (TA’s report, p.3) was classified in both the ‘Exposure’ and ‘Focus’ categories, given the characteristics of the document to which the teacher refers to.

To increase the trustworthiness of this study (Given, 2008), content analysis was initially performed by the first author of this study and reviewed by the other authors. Discrepancies related with the inclusion in the categories were discussed and resolved by consensus. The tables 1, 2, and 3 (in the next section) represent the analysis framework and present the averages and respective standard deviation of the frequency of occurrence of each science teaching strategy developed by G2.

## ***3.4 Presentation and discussion of results***

This section briefly contextualizes the curricular module developed by G2 and presents the results of the content analysis on the teaching strategies. The significance of these results is discussed, related to the literature and, whenever possible, illustrated with evidence from the collected data.

The analysed CoP planned a **curricular module** under the Portuguese curricular topics: ‘Sustained exploitation of geological resources’, from the academic subject of ‘Biology and Geology’; and ‘From the atmosphere to the ocean: Solutions on Earth and to the Earth’, from the academic subject of ‘Physics and Chemistry’. These subjects and topics are part of the secondary course of ‘Science and Technology’, particularly of the year 11, which is usually attended by 16/17 year old students. In the 2006/07 school-year, G2 developed a curriculum integrated field trip (Marques & Praia, 2009; Orion, 2007) that included a visit to the Quarry Quinta do Moinho (located in Vila Nova de Gaia, Portugal), whose educational objectives were identified in Pinto and colleagues (2009). After the initial enactment (by TC) and evaluation, the module and curriculum materials were redesigned and an adaptation of these was done to fit a field trip to the Quarry Feifil (located in Viseu, Portugal). It is noteworthy the fieldwork was always carried out in a quarry near the schools where the curricular module was enacted: ‘The choice of these quarries as a learning context was due to (...) a close relationship with the schools where the teaching resources would be implemented’ (Pinto *et al.*, 2009). Note also that the field trip was organised **following Orion’s model** (2007), which provides three learning moments properly articulated: before the field trip, the actual field trip and after the field trip. Therefore, it requires a phase of preparation of the field trip, to reduce the novelty-space in its cognitive, geographic and psychological aspects. In other words, this is a phase of contextualization of the aimed learning. This is followed by a phase of students’ interaction with the natural phenomena on the site of the field trip, through concrete activities. After performing these activities, follows a more abstract conceptual learning, back in the classroom.

Tables 1, 2 and 3, which follow, present the average (Ñ) and standard deviation (α) of the frequencies of the actions (teacher/students), theirs protagonists and resources in each field trip stage and in the curricular module. In each column, we underlined the highest value. Table 1 shows that before the field trip the more exploited **action** was ‘Exposure’, which is consistent with the need to contextualize the field trip and to reduce the novelty-space (Orion, 2007). The following quote exemplifies an action of this kind: ‘PowerPoint presentation where the teacher presents: the purpose of the field trip, the route and the stopping points; ...’ (TA’s report, p.3). In the phases during and after the field trip the most frequent action was ‘Manipulating instruments’, as illustrated by the quote ‘The working group that collected water [in the quarry] must perform its analysis [in the lab]’ (TB’s report, p.19). Considering the total of actions of the curricular module, the most frequent one remains the ‘Exposure’. Many of these ‘exposures’ were carried out by groups of students, to share with their classmates and teacher(s) the results of their intra-group’s debates and researches. As an example, we present the following quote, ‘... each working group presents to the Class their observations [during the field trip], their conclusions and the questions that still remain unanswered.’ (TD’s report, p.8).

Table 1 - Average (Ñ) and standard deviation (α) of the frequency of occurrence of teacher's (T) or student's (S) actions, in the triangulated lesson plans

| Type of action | Description of the action | Before Ñ (α) | Field trip Ñ (α) | After Ñ (α) | Total Ñ (α) |
|---|---|---|---|---|---|
| Focus | The protagonist (T or S) defines and/or negotiates the learning objectives, orally or with the support of educational resources. | 2,0 (0,0) | 0,0 (0,0) | 0,0 (0,0) | 2,0 (0,0) |
| Planning | The protagonist (usually S) decides on and makes arrangements for the tasks to be performed, by whom, how and with what resources, orally or with the support of educational resources. | 2,0 (0,0) | 0,0 (0,0) | 0,0 (0,0) | 2,0 (0,0) |
| Exposure | The protagonist (T or S) presents ideas orally or with the support of educational resources, without major interventions of others and with a longer or shorter duration. | <u>6,5 (1,7)</u> | 1,5 (0,6) | 2,0 (0,0) | <u>10,0 (1,8)</u> |
| Questioning | The protagonist (T or S) raises questions orally or written, to be answered by S. | 2,5 (1,3) | 2,0 (0,0) | 1,5 (0,6) | 6,0 (1,6) |
| Debate | The protagonist (usually S), in interaction with other protagonists, analyses and orally exchanges ideas on a topic to reach a consensus. | 4,5 (1,3) | 0,3 (0,5) | 0,5 (0,6) | 5,3 (1,5) |
| Research and synthesis | The protagonist (usually S) collects information/data, processes it and synthesizes it, with the support of the needed educational resources. | 2,0 (0,0) | 1,0 (0,0) | 1,8 (0,5) | 4,8 (0,5) |
| Manipulating instruments | The protagonist (usually S) observes and interacts with laboratory or fieldwork instruments. | 0,0 (0,0) | <u>3,3 (0,5)</u> | <u>2,5 (0,6)</u> | 5,8 (1,0) |

Table 1 also shows that the developed curricular module include other actions, as (by decreasing order of frequency): ***i)*** 'Questioning', which occurs in all three phases, promotes critical thinking (Vieira & Vieira, 2005), and has high impact on students learning (Johnson *et al.*, 2012; Schroeder *et al.*, 2007); ***ii)*** 'Manipulating instruments', which has been recognized as a strategy that positively affects pupils learning and is indicative of a practical educational process (e.g., Furtak *et al.*, 2012; Minner *et al.*, 2010; Schroeder *et al.*, 2007; Wise, 1996); ***iii)*** 'Debate' occurs in all three phases and promotes student's active involvement in his/her own learning (e.g., De Pro Bueno, 1999; Furtak *et al.*, 2012; Tate, 2003; Vieira & Vieira, 2005); ***iv)*** 'Research and synthesis' was present in all three phases and is also a recommended strategy in the literature (e.g., Johnson *et al.*, 2012;

Schroeder *et al.*, 2007; Wise, 1996; Wise & Okey, 1983); and ***v)*** 'Focus' and 'Planning', especially before the field trip, is recommended in the literature as well (e.g., Marzano, Gaddy, & Dean, 2000; Wise, 1996; Wise & Okey, 1983). It is noteworthy that, in this curricular module, each action/set of actions performed in small group was followed by a presentation to the class of their findings and/or concerns, with or without debate, with or without a teacher's synthesis, which allowed sharing and negotiation of meanings, as recommended by De Pro Bueno (1999).

Table 2 shows the **protagonists** of the curricular module actions were (in decreasing order): ***i)*** students in small group; ***ii)*** teacher; ***iii)*** students and teacher sharing protagonism; and ***iv)*** individual student. Consequently, this curricular module is based on students' collaborative work, given the large number of actions performed that way, as illustrated by the following quote:

> '*The teacher organizes the class in four working groups and asks them to continue the discussion (...) the working groups present to the class the obtained conclusions. (...) The teacher suggests that all work groups perform a research activity on the Internet (...)*' (TE's report, p.24).

As stated before, collaborative learning has been identified as one strategy with high positive impact on student's learning (e.g., Furtak *et al.*, 2012; Johnson *et al.*, 2012; Marzano, Gaddy, & Dean, 2000; Schroeder *et al.*, 2007). The same table shows a higher frequency of students' protagonism (in group or individual) comparing to the teacher's. Therefore, this curricular module is characterised by the students' active involvement in their learning, which is widely advocated by the literature (e.g., Herbert *et al.*, 2003; Minner *et al.*, 2010; Taraban *et al.*, 2007; Vieira & Vieira, 2005).

Table 2 - Average (Ñ) and standard deviation (α) of the frequency of different protagonists, in the triangulated lesson plans

| Protagonist of the action | Before Ñ (α) | Field trip Ñ (α) | After Ñ (α) | Total Ñ (α) |
|---|---|---|---|---|
| Teacher | 4,3 (1,5) | 0,5 (0,6) | 1,0 (0,0) | 5,8 (1,0) |
| Individual student | 0,5 (0,6) | 1,5 (1,0) | 0,0 (0,0) | 2,0 (1,4) |
| Students in small groups | <u>8,8 (2,2)</u> | <u>2,3 (0,5)</u> | <u>4,0 (0,0)</u> | <u>15,1 (2,4)</u> |
| Teacher and students in the Class - shared protagonism | 3,0 (1,4) | 0,3 (0,5) | 0,5 (0,6) | 3,8 (1,5) |

Finally, table 3 shows several actions not associated with a clear statement of the needed **resources**, especially before the field trip. When they are explicit, the resources include: ***i)*** 'Technology related with static text and image', especially when such resources are available (before and after the field trip) and were used to display teacher's (before the field trip) or work groups' (after the field trip) electronic presentations; ***ii)*** 'Laboratory and fieldwork material', particularly during and after the field trip, to collect and analyse water and rock samples, make photographic records, microscopic observations and measurement of noise levels; ***iii)*** 'Worksheet produced by the teacher or other material provided by the teacher', which included a fieldwork guide and legislation on quarries, and also, in TE's case, a document to guide the preparation of the field trip and to integrate it in a broader curriculum study context; and ***iv)*** 'Interactive technology', in the first and third phases, usually to make Internet researches or, in the case of TD, to use Google Earth to reduce the novelty-space. On the other hand, this table also shows the lack of use of the traditional blackboard and textbook, contrasting with results of other studies (De Pro Bueno, 1999; Herbert *et al.*, 2003). The overcoming of the teaching mainly supported by these traditional resources is a desirable outcome, which emerged from the analysed data.

Table 3 - Average (Ñ) and standard deviation (α) of the frequency of different resources, in the triangulated lesson plans

| **Resources to support the action** | **Before Ñ (α)** | **Field trip Ñ (α)** | **After Ñ (α)** | **Total Ñ (α)** |
|---|---|---|---|---|
| The resources are not explicit | 8,0 (5,5) | 0,5 (0,6) | 1,5 (0,6 | 10,0 (5,2) |
| Worksheet produced by the teacher or other material provided by the teacher (for example, a newspaper article or legislation) | 2,5 (0,6) | 1,0 (0,0) | 1,0 (0,0) | 4,5 (0,6) |
| Technology related with static text and image (for example, computer and datashow to display electronic non interactive presentations) | 4,0 (1,4) | 0,0 (0,0) | 2,0 (0,0) | 6,0 (1,4) |
| Interactive technology (for example, computer with Internet access and specific software) | 1,3 (0,5) | 0,0 (0,0) | 1,0 (0,0) | 2,3 (0,5) |
| Laboratory and fieldwork material (for example, geological map, rock samples, camera, microscope or test tubes) | 0,0 (0,0) | 3,3 (0,5) | 2,5 (0,6) | 5,8 (1,0) |

With the exception of one teacher, the lesson plans in the teachers' final reports presented the **educational objectives** of the developed teaching strategies. However, it seems there was no consensus regarding this aspect. One of the teachers presented the following: ***i)*** general competences, e.g., 'Mobilising scientific, technological and cultural knowledge' (TA's report, p.25); ***ii)*** the elements to be taken into account during the assessment and their weigh, e.g., 'quality of the students' answers in the fieldwork guide - 10%' (*idem*, p.26); and ***iii)*** learning indicators, e.g., 'Relates magmatic rocks' characteristics with its genesis' (ibid., p.27). Two other teachers presented: ***i)*** different general competences, e.g., 'Decision making' (TB's report, p.13, and TE's report, p.23); ***ii)*** core competencies, e.g., 'Communication' (TB's report, p.13, and TE's report, p.23); and ***iii)*** evaluation criteria, e.g., 'oral participation, organization of the collected information and use of scientific language (communication competences)' (TB's report, p.21, and TE's report, p.29). The CoP's members acknowledged that one of the biggest difficulties they encountered was the definition of educational objectives and, therefore, the assessment of student's learning (Fernandes *et al.*, 2009).

Considering pupils' **assessment**, although it is not explicit in the lesson plans, some items, such as 'The Biology and Geology Teacher (BGT) questions students about key concepts of the processes related to magmatic rocks formation, taught in the previous programme unit, and about man's use of geological resources' (TB's report, p.14), were recognised as having a diagnostic assessment nature. This is due to the fact that they allow the identification of the previous conceptual learning related to the topic. Although the given example is related to questioning, the analysis of the lesson plans suggests that all teachers used, implicitly, the debate for diagnostic evaluation purposes. This mobilization of previously acquired knowledge is related to the following categories that promote pupils' learning: 'enhanced context strategies' (Schroeder *et al.*, 2007), 'activating prior knowledge' (Marzano, Gaddy, & Dean, 2000) and 'conceptual facet' of the cognitive dimension of inquiry (Furtak *et al.*, 2012). Nonetheless, other studies suggest the use of students' prior knowledge does not seem to be common (Herbert *et al.*, 2003).

Regarding formative and summative assessment, we could not associate any strategy with neither. We admit that formative assessment could have been implicit in the curricular module, as suggested by the quote 'Each work group presents to the Class their key findings obtained during the activities, seeking to answer the questions raised during the field trip' (TD's report, p.9). However, no empirical evidence was found related to a systematic and intentional assessment to support pupils learning. This aspect did not conform to one of the literature's commendations: to give feedback regarding students' performance during the process of teaching and learning (Furtak *et al.*, 2012; Marzano, Gaddy, & Dean, 2000; Schroeder *et al.*, 2007). Similarly, we can admit pupils' answers in the field trip guides and their presentations could have been used for summative assessment, as suggested by the researchers:

> '*Let's not forget that it is also important to know what happened in terms of achieved learnings (...). It will be possible to analyse this aspect from the final test and pupil's answers in the field trip guide as well.*' (Forum: G2's work plan; Date: 2007/05/27; Author: R1).

However, as there is no reference to neither the test or the pupils' answers to the field trip guide, the data collected does not have evidence on the summative assessment made.

These difficulties in pupil assessment, here reported, are acknowledged by the group (Morgado *et al.*, 2008) and seem to be common in Portuguese educational contexts (Fernandes & Gaspar, 2014; Rosa, 2010).

Remarkably, G2 employed a strategy referred in the literature as having a high positive impact on student's learning (e.g., Johnson *et al.*, 2012; Marzano, Gaddy, & Dean, 2000; Tate, 2003), but which could not be included in one of this study's dimensions of analysis (action, protagonist and resources):

> '***Enhanced context strategies****. Teachers relate learning to students' previous experiences or knowledge or engage students' interest through relating learning to the students'/school's environment or setting (e.g., using problem-based learning, taking field trips, using the schoolyard for lessons, encouraging reflection)*' (Schroeder *et al.*, 2007, p. 1446).

G2 also exploited '**Enhanced materials strategies** - Teachers modify instructional materials (e.g., rewriting or annotating text materials, tape recording directions, simplifying laboratory apparatus)' (*idem*, p. 1445), as they evaluated the process of development of the module itself, as well as students' perceptions about their learning of group work competencies. This evaluation aimed at the redesign of the curricular module, before the second implementation. This scenario contrasts with most results in the literature, since summative assessment seems to prevail in the teachers practices (Herbert *et al.*, 2003), focusing mainly on the learning products, rather than on the learning process itself (Fernandes & Gaspar, 2014; Lucas & Vasconcelos, 2005).

**In summary**, the curricular module developed IPEC's G2 promotes pupils' active role, in collaboration with peers in work groups or involving the whole class, being the learning process contextualized in real phenomena from the near environment, through a curriculum integrated field trip. In addition, the analysis performed revealed the curricular module includes a great diversity of teaching and learning strategies, one of the features highlighted by the CoP's members themselves (Pinto *et al.*, 2009). According to the literature, the combination of several different strategies promotes students' learning (e.g., Marzano, Gaddy, & Dean, 2000; Schroeder *et al.*, 2007; Tate, 2003; Vieira & Vieira, 2005), since it allows to address different learning needs and to develop a diversity of competencies. Hence, the results presented and discussed in this section revealed that this CoP applied research-based teaching strategies into the design of their curricular module. This result is in line with studies of teacher communities reported in the literature (Roblin *et al.*, 2014) suggesting that the support provided by these communities promotes the link between research commendations and teaching practice.

Studies that do not involve the analysis of teaching practices during or following a specific TPD intervention reveal a different education reality (e.g. De Pro Bueno, 1999; Capps & Crawford, 2013; Herbert *et al.*, 2003; Johnson *et al.*, 2012). The De Pro Bueno (1999), during a study of the planning documents of twelve teachers, identified a high use of teacher exposure and some forms of pupils' individual work, essentially those recommended in textbooks. The duration of the same type of activity varied from teacher to teacher; yet, in some cases the teacher explained the topics and students listened to him/her during three consecutive lessons. The results of this study showed low levels of students' protagonism and some teacher distrust of group work. Herbert and colleagues (2003) also identified teacher-centred practices of exposure and/or based on the textbook. Johnson and colleagues (2012) stated teachers often choose to tackle the great diversity of the topics from the programme of study with low depth, which results in teacher-centred teaching and in fewer opportunities to inquiry. More recently, Capps and Crawford (2013) studied the state of-use of inquiry-based instruction and explicit instruction about nature of science highly motivated and well-qualified teachers. Their results showed that even teachers with this profile were failing to fully understand and enact research-based approaches, and thus the authors claimed the need to better support teachers in doing this.

## ***3.5. Final considerations***

This last section is a summing-up of this study's contribution to the literature about teaching strategies in SE, especially in regard to the impact online CoP involving teachers and researchers can have on them. Tendencies about the evolution of the teaching strategies of the teachers involved in IPEC's G2 are also presented. Some possible explanatory hypotheses of the obtained results are advanced, as well, which should be analysed in future research. At last, some limitations of this study are also pointed out.

**The results** from the content analysis show that this online CoP developed a curriculum integrated field trip (Orion, 2007) contextualized in the near environment of the schools where it was enacted (e.g., Furtak *et al.*, 2012; Johnson *et al.*, 2012; Marzano, Gaddy, & Dean, 2000; Schroeder *et al.*, 2007). As recommended in the literature (e.g., Schroeder *et al.*, 2007; Tate, 2003; Vieira & Vieira, 2005), the curricular module combines a diversity of strategies, being the most frequent: ***i)*** the exposure with or without the support of electronic presentations, by the teacher or students, during the first and the last phases of the field trip, respectively; ***ii)*** the questioning, during all phases of the field trip; ***iii)*** the manipulation of instruments by the students, in particular, material needed in the field and in the laboratory; ***iv)*** the debate of concepts, procedures, etc., in small groups or in the class; ***v)*** the research and synthesis of information from different sources (Internet and field); and ***vi)*** the focus on the aimed learning and the planning of the tasks to be performed during the field trip. The students' active role, in small groups, was the base of the developed module. The main resources mobilised were: ***i)*** new technologies of communication, e.g., to expose information and to reduce the novelty-space; ***ii)*** several laboratory and field instruments, e.g., to collect and analyse samples of water; and ***iii)*** the fieldwork guide, conceived by the CoP, as well as legislation about the exploitation of quarries. We remind that the application of research-based frameworks into the design of the curricular module is in line with studies reported in the literature (Roblin *et al.*, 2014). However, it seems that when there is not a specific TPD program involved in the research study, even teachers classified as highly-motivated and qualified struggle to enact teaching in line with the literature (Capps & Crawford, 2013).

Some aspects of the analysed practices were **not as promising** as those above-described because no evidence of a teaching and learning process with a continuous feedback on student learning was identified. This kind of issue seems to be common in teaching practices, according to the analysis of Rosa (2010) and Fernandes e Gaspar (2014). However, this CoP adopted a two cycles of development of the curricular module, which allowed its evaluation and improvement, as well as colleting the students' perceptions about their learning of work group competencies (L. Marques *et al.*, 2008; Marques, Loureiro, & Marques, submitted), a desirable but uncommon practice among teachers (Leite, 2010).

The results presented and discussed in the previous section are evidence of an evolution of the CoP's teaching practices, from a transmissive teaching (as pointed out in Marques, 2008) to strategies acknowledged in the literature as having a positive impact in pupils' learning (e.g., Furtak *et al.*, 2012; Johnson *et al.*, 2012; Meyer & Avery, 2010; Schroeder *et al.*, 2007). In addition, a previous study showed this CoP developed challenging innovative practices, enacted by the teachers of this social group and by their school colleagues, who were not directly involved in the IPEC project (Marques, Loureiro,

& Marques, 2011). To the improvement of the practices of these teachers some **factors** may have contributed:

- collaborative work between teachers and researchers in a professional learning community (Roblin *et al.*, 2014; Vanderlinde & Braak, 2010), which required an active interaction of the teachers with peers and specialists (Avalos, 2011; Borko, 2004; Dede *et al.*, 2009);
- reduction of the teachers' feeling of isolation (Avalos, 2011);
- long period of collaboration within the CoP (Avalos, 2011; Borko, 2004; Dede *et al.*, 2009);
- higher teacher reflectiveness (Avalos, 2011; Holmes, 2013) and the self-evaluation of their own practices (Barab, MaKinster, & Scheckler, 2004); and
- activities centred in teachers practices and needs (Dede *et al.*, 2009; Tytler *et al.*, 2011).

The profile of the members of this CoP may also have been a relevant factor, since all teachers had done post-graduate courses (four had a master's degree in the area of outdoor learning activities) and the researchers were all doctorate in SE and had extensive experience in this field. Therefore, the above presented factors should be submitted to **further research**.

The authors of this study acknowledge that their research method, a single case study (Yin, 2009), does not allow proposing that every online CoP, involving teachers and researchers in SE, will promote the improvement of teaching practices. It is not also possible to point out which conditions or factors will allow that desired improvement. Yet, it is a contribution to the development of a framework on such factors, which should be further studied. These can be seen as **limitations**, nevertheless, the single case methodological option was a deliberate one, sustained in the need of a deep understanding of the selected phenomenon and in the exploratory nature of this study, due to the lack of previous related research.

In sum, this **contribution** allowed to identify the teaching strategies developed by an online CoP of teachers and researchers in the SE context and to verify these are predominantly coherent with research indicators on effective teaching strategies. Therefore, this study presents evidence that the collaborative work in online CoP can contribute to the improvement of teaching practices.

The authors of this study hope it can contribute to the literature about the potential of online CoP involving teachers and researchers in promoting the improvement of science teaching strategies. It also may be considered relevant by science teachers in different places in the world who wish to diversify and adapt their range of teaching strategies, sustaining their options in SE research.

***Acknowledgements***

The authors acknowledge the engagement of the teachers involved in the project IPEC and appreciate their collaboration during the review of the data triangulated. The authors acknowledge also the support of the Portuguese Foundation for Science and Technology, through the funding given to the Project IPEC (POCI/CED/58825/2004) and to the doctoral studies of the first author (SFRH/BD/36177/2007). Finally, the authors acknowledge as well the contribution of Ricardo Pereira, who provided his external insight on the developed analysis.

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