
Contributions to Science Teaching Practice of an Online Community of Practice of Teachers and Researchers

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Abstract

Communities of practice (CoP) can promote teachers' professional development (TPD) and change their practices. However, empirical evidence is still scarce. To contribute to address this shortcoming, a single case study was carried out aiming the analysis of an online CoP involving teachers and researchers. Data collection included the used platform statistic data and posts automatically recorded, as well as the CoP's documents. Content analysis took into account Clarke and Hollingsworth's (2002) Interconnected Model of Teacher Professional Growth (IMTPG) and was centred in (a) the external domain and the curricular development (CD) practices; (b) the domain of the consequences of the work carried out regarding the developed science teaching strategies; (c) the evidence of their innovative nature; and (d) the CD principles enacted. The results show that (a) the members' participation varied during the interaction period and their dynamic fits an adaptation of Wenger et al.'s (2002) stages of development of a CoP, with two action-research cycles; (b) the CoP developed diverse teaching strategies coherent with recommendations from the literature; (c) the teaching practices were innovative and challenging; and (d) the CoP enacted several principles of CD suggested in the literature. Moreover, the empirical results validated the dimensions of the IMTPG.

Abstract in Portuguese

As comunidades de prática (CoP) podem promover o desenvolvimento profissional de professores e mudar as suas práticas, existindo, porém, poucas evidências empíricas. Contribuindo para reduzir esta lacuna, efetuou-se um estudo de caso único cujo objetivo foi a análise de uma comunidade de prática *online*. A recolha de dados as estatísticas da

plataforma usada, mensagens gravadas automaticamente e documentos da CoP. A análise de conteúdo teve em conta o *Interconnected Model of Teacher Professional Growth* (IMTPG) de Clarke e Hollingsworth (2002) e centrou-se: (a) nos domínios externo e das práticas de desenvolvimento curricular (DC); (b) no domínio das consequências do trabalho realizado no que respeita às estratégias de ensino de ciências; (c) nas evidências de inovação das práticas; e (d) nos princípios de DC operacionalizados. Verificou-se que (a) a participação dos membros variou ao longo do tempo e a sua dinâmica se enquadra numa adaptação das fases de desenvolvimento de CoP de Wenger et al. (2002), com dois ciclos de investigação-ação; (b) a CoP desenvolveu diversas estratégias de ensino coerentes com recomendações da literatura; (c) as práticas letivas foram inovadoras, do tipo *challenging*; e (d) a CoP operacionalizou vários princípios de DC sugeridos na literatura. Os resultados empíricos validaram também as dimensões do IMTPG.

Keywords: online communities of practice, teacher's professional development, Interconnected Model of Teacher Professional Growth, science teaching practices, curricular development, innovation.

Introduction

The open and distance learning movement is increasingly growing and can take different formats and shapes. One relatively new form of learning, particularly about practices, is a consequence of the participation in social group, as communities of practice or CoP (Lave & Wenger 1991; Wenger, 1998). CoP work on common interests, shared objectives and resolve problems that are genuine and emergent from the practices of the CoP's members. When these communities use online communications Tools, such as discussion boards or even mobile phones, to allow interaction between the members and with artefacts or resources available in an online platform, they are usually called online CoP.

Over the years, CoP have been extensively used to support professional development (PD) and manage knowledge within organizations, in several professional contexts, such as midwives, Liberian tailors, navy quartermasters and meat cutters (Lave & Wenger, 1991) or even teachers (e.g., Cuddapah & Clayton, 2011; Howell, 2007). However, and particularly in the Education area, studies frequently focus on the description of how CoP can be created and sustained, as well as their advantages for PD without presenting evidence of change in the teaching practices of their members (Avalos, 2011; Dede, 2006; Lai et al., 2006). It is also uncommon narratives of work

carried out in CoP involving teachers and researchers. Hence, this work aims to contribute to fill this gap, reporting the contributions of an online CoP, involving teachers and researchers, to improve Science Education (SE) teaching practices.

In line with the above mentioned, a single case study was carried out. An online CoP, involving teachers and researchers in the domain of SE was analysed. The online CoP members collaborate, using diverse online communication tools, to develop a curricular module related with sustainably (Marques, 2014). The analysis was performed taking into account the Interconnected Model of Teacher Professional Growth (IMTPG) of Clarke and Hollingsworth (2002) and based on empirical data concerning the interactions between the online CoP members and documents created during the life cycle of the community.

Clarke and Hollingsworth (2002) claim that teacher professional growth occurs through reflection and enactment in four domains: external (the stimulus triggering the professional growth), personal (i.e., the teacher's knowledge, beliefs and attitudes, in sum, their competencies), practice (the teacher's experimentation in his/hers professional actions), and consequence (the acknowledged consequences of the experimented actions). By presenting these domains interconnected, the model proposes that a change in one domain can induce change(s) in another domain(s). Thus, this model recognises multiple possible pathways in professional growth, and, therefore, the occurrence of learning in different contexts and formats.

The developed work, the PhD of the first author, was based on two assumptions, arising from the literature:

- online CoP have the potential to contribute to teacher professional growth (Dede, 2006; Lai et al., 2006; Loureiro et al., 2009); and
- a change in a teacher external domain, e.g., through the participation in an online CoP, can induce changes in its practices and consequence domains (Clarke & Hollingsworth, 2002).

This study, as other previous studies (Justi & Driel, 2006; Witterholt, Goedhart, Suhre, & Streun, 2012), uses the IMPG to support the understanding of teacher professional growth, regarding teaching practices developed in an online CoP. The research questions were defined to focus the analysis in some of the IMTPG domains. They are:

1. What are the dynamics of interaction of the selected online CoP? – external and practice domains;

2. To what extent are the teaching strategies mobilised within the selected online CoP coherent with indicators, from SE research, regarding effective strategies concerning pupils' learning? – consequence domain;
3. What is the potential of the work carried out by the members of online CoP for the development and adoption of innovative teaching practices and, thus, for PD? – consequence domain;
4. What principles of curricular development (CD), recommended in the literature, were enacted during the development of the curricular module by the online CoP? – consequence domain.

Each one of these questions was analysed during the course of the PhD of the first author, as previously referred, and is coherent organisation (made in the thesis introduction and conclusions) of four papers published in peer-reviewed journals as follows: question 1 in Marques, Loureiro, and Marques (2016), question 2 in Marques, Loureiro, and Marques (2015a) question 3 in Marques, Loureiro, and Marques (2011) and question 4 in Marques, Loureiro, and Marques (2015b). This contribution is based in the conclusions of the PhD and, thus, a synthesis of the main results and recommendations regarding measures to promote the contributions of online CoP aiming the innovation of SE teachers' practices. Figure 1 shows the relation between the research questions, the IMTPG and the emergent recommendations. The explanation of the connection between the IMTPG domains will be made in the final section of the paper.

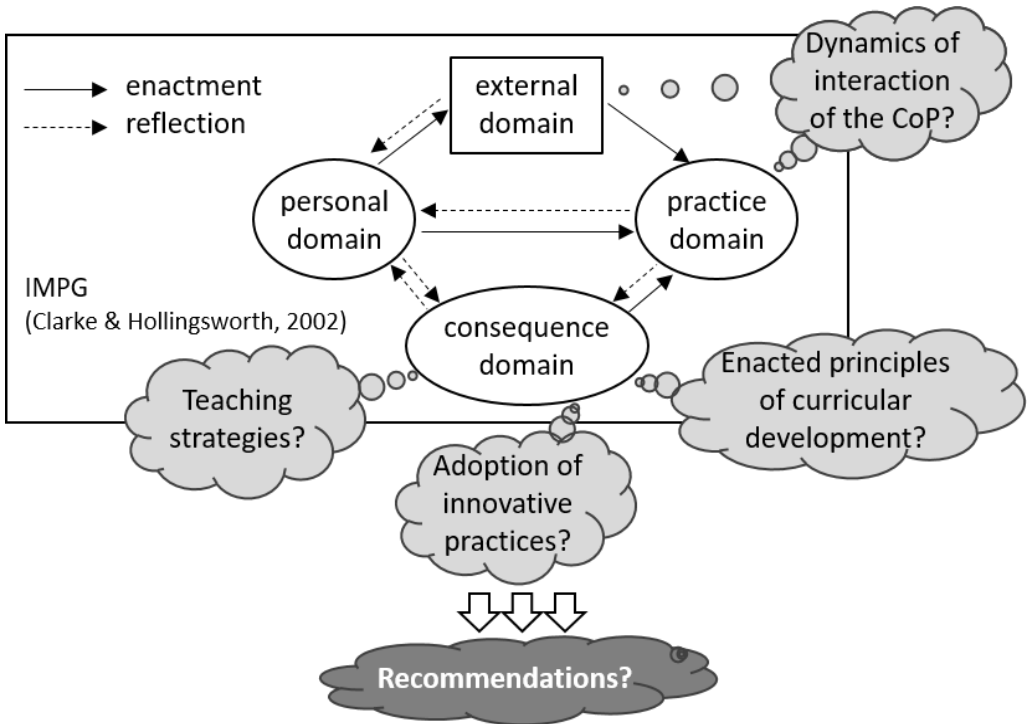


Figure 1. Relation between the research questions, the Interconnected model of teacher's professional growth or IMTPG (Clarke & Hollingsworth, 2002), the published papers and the emergent recommendations

Methodology and contextualisation

The nature of the study is qualitative descriptive and exploratory (Berg, 2001; Yin, 2009), as the documentation of the contribution of teacher participation in online CoP to teaching practice improvement is still scarce (Avalos, 2011; Lai et al., 2006). Both the contemporaneity of the phenomena (in-depth study the selected online CoP), the real life context studied, and the type of research questions proposed, justify the option for a single case study methodology (Yin, 2009). Additionally, the aim was to deeply understand a single case, without concerns to compare it with other cases and to generalise the results (Yin, 2009).

The studied online CoP was established and sustained under a Portuguese research project, named "Investigação e práticas lectivas em Educação em Ciência: Dinâmicas de interação - IPEC" (Research and practices in Science Education; dynamics of interaction), financed by the Portuguese Foundation for Science and Technology (FCT). In the context of the project four group were created. One of these groups, G2,

was selected as the object of the present study since it presented several features of an online CoP. Namely the members had a common goal, a shared practice, developed a common repertoire, had a high sense of community, extensively used online asynchronous community tools, in particular discussion forums (more suitable to promote reflexivity), and collaborated during a long period, almost two school years (Marques, 2008). Without the linearity and time constraints of synchronous communication tools, where messages are typically brief, informal, and superficial, asynchronous conferences are recognized in the literature as more conducive to higher order thinking through literate writing (Lapadat, 2002) and were the ones chosen by the group to interact at a distance.

G2 consisted of five female teachers (four specialists in *biology and geology* and one in *physics and chemistry*), and three researchers in SE (two male and one female). The teachers had a long teaching experience (11 to 21 years), most of them had a post-graduation in SE, and all of them used information and communication technologies (ICT), mainly word processor, Internet browser and e-mail. None of these teachers had experience using ICT in distance learning. Regarding the researchers, all had a PhD degree and more than 20 years of research experience. Two of them used ICT tools as the teachers did and one was an expert in educational technology, thus used ICT with several objectives, including teaching. The group developed a curricular module related with the sustainability of a quarry and used a field trip strategy accordingly with Orion (1993). The author posits that a field trip has three moments properly articulated: before the field trip, the actual field trip and after the field trip. Before the field trip a preparation phase is carried out to reduce the novelty space in its cognitive, geographic and psychological aspects. In other words, this is a contextualization phase of the aimed learning. This phase is followed by a phase where students interact with the natural phenomena on the site of the field trip, through concrete activities (observation, data gathering, questioning the quarry responsible ...). Back in the classroom, after the visit, the students analyse and organise the data and derive conclusion, in other words, this phase aims more abstract conceptual learning.

To reply the first question (What are the dynamics of interaction of the selected online CoP?) two years of online interactions regarding the planning, implementation and assessment of a curricular module developed by G2 and all the documents produced in this context, were analysed. The platform statistics were downloaded in order to analyse the dynamic of the interaction (number of posts by month along the two years). The posts and the documents were submitted to content analysis to characterise the

dynamic of online CoP phases. The analysis scheme was produced as a result of a literature review, regarding CoP life cycle, allowing to compare several models of CoP phases of development (Gongla & Rizzuto, 2001; Grossman et al., 2000; Howell, 2007; McDermott, 2000; Wenger, 1998; Wenger, McDermott, & Snyder, 2002). Content analysis was performed using an adaptation of Wenger et al.'s model, integrating features of other analysed, coherent with G2's empirical data. The resultant instrument is one of the contributions of PhD and is presented in the annex I. Concerning the online CoP work strategy, it was contrasted with the action-research cycles of Altrichter and colleagues (1993). More details regarding the methodological options of this particular study are presented in Marques et al. (2016).

To answer the research question 2 (To what extent are the teaching strategies mobilised within the selected online CoP coherent with indicators, from SE research, regarding effective strategies concerning pupils' learning?), a literature review of international studies, particularly meta-analyses of strategies with impact on pupils' science learning (Furtak et al., 2012; Marzano, Gaddy, & Dean, 2000; Schroeder et al., 2007; Wise, 1996; Wise & Okey, 1983) was performed. The emergent instrument of analysis (Annex I) was applied to the curricular module plan and development, its members' final reports and the group's published papers and communications. More details regarding this work are presented in Marques et al. (2015a).

Regarding research question 3 (What is the potential of the work carried out by the members of online CoP for the development and adoption of innovative teaching practices and, thus, for PD?), the study of the innovative features of G2's practices was performed with literature descriptors proposed by Jaskyte et al. (2009) and Cachapuz, Praia, and Jorge (2002). Here, the empirical data was submitted to content analysis using these authors' indicators of innovative teaching practices in SE (Annex III). Once again, the resulting analysis scheme is one contribution of this work. More details about this analysis' methodology are presented in Marques et al. (2011).

At last, to address research question 4, G2's enactment of CD principles, identified through a review of international literature (e.g., Anderson & Rogan, 2011; Gaspar & Roldão, 2007; Kelly, 2009; Pacheco, 2005), was also analysed. A qualitative analysis instrument with six descriptors was proposed and applied to the CoP's empirical data. Figure 2 synthetize the CD principles that emerged from the literature. More details regarding this work are presented in Marques et al. (2015b).

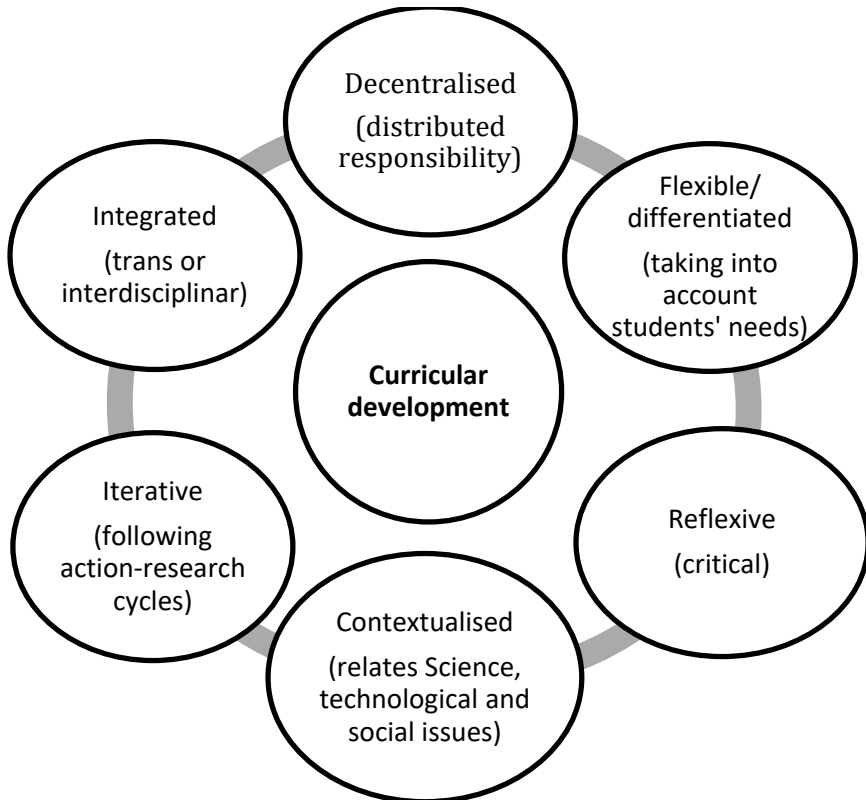


Figure 2. Schematic synthesis of the CD principles

Results presentation and discussion

As mentioned before, the research guided by question 1 addresses the external and practice domains of the IMTPG. Regarding G2 teachers' *external domain*, the data collected allowed acknowledging the following CoP's phases of development in G2's online interactions:

- Potential phase – involved the exploitation of the online platform used for the interaction between the G2 members, the discovery of members' common interests regarding the teaching practice and the negotiation of the group work plan, taking into account problems emerging from the teacher's practices (see the description below);
- Coalescing phase – G2's members shared teaching experiences, discussed educational concepts, made recommendations, read academic documents about SE (journal articles, reports, ...), and developed a common practice – a curricular module that was implemented by one of the teachers;

- Maturing phase – comprised the assessment of the curricular module and the identification of the cutting edge issues, particularly the definition of the module’s educational aims and assessment strategies. As a consequence, the curricular module and all the teaching materials were revised to be enacted by all the teachers. The implementation was made in collaboration with school colleagues not previously involved in the project IPEC;
- Stewardship – G2 developed a sense of property and pride in the developed work, which was translated into its dissemination during the implementation of the revised module and in scientific meetings (Marques et al., 2016).

The Figure 3 presents the statistics of the interaction during the development of the curricular module by G2 and the online CoP phases along the interaction period that fits an adaptation of Wenger et al.’s model, as referred in the previous section.

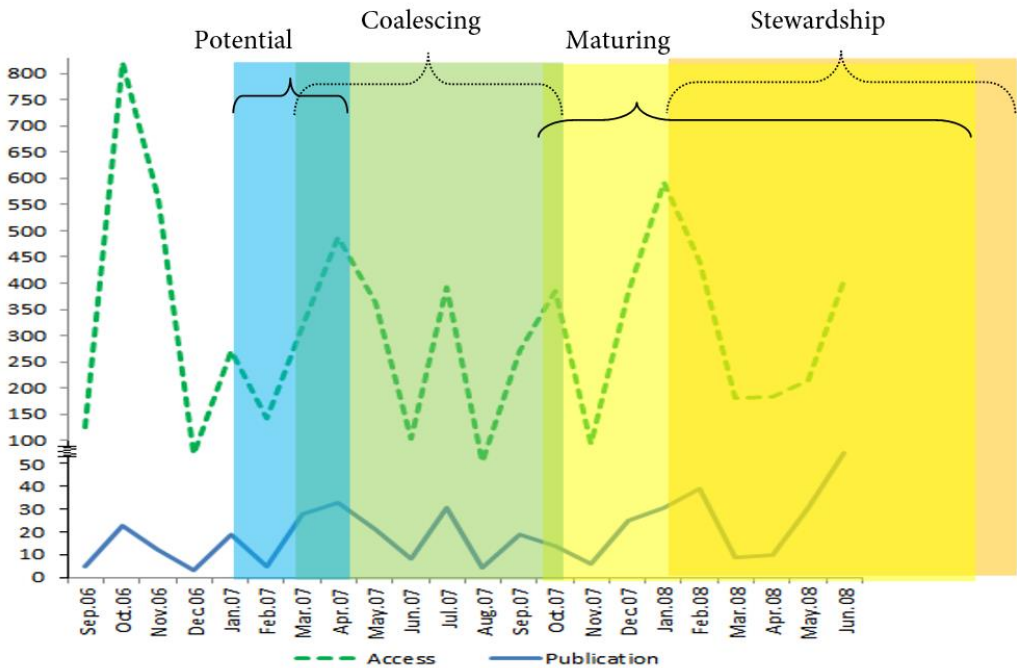


Figure 3. Frequency of access and publication of messages in fora by the teachers from G2

Concerning the *practice domain* and the description of the CoP’s phases, it can be inferred that, during the course of about two scholar year, G2’s collaboratively developed a curricular module performing two cycles of action-research, similar to the cycles proposed by Altrichter and colleagues (1993): planning, implementation and

evaluation. The starting point (in the *external domain*) was a reflection enacted by a questionnaire where teachers were invited to share their problems related with scientific topics and teaching strategies. This allowed the identification of teaching practices problems by the teachers themselves and a sense of ownership during the development of the curricular module materials and its implementation. During the evaluation phase, new problems emerged related to the definition and alignment of the module objectives with the assessment strategies. This led to an unexpected collaborative processes; a working journey with invited experts (highly valued by the teachers) was organised to discuss the new problems. The reflection during the journey initiate another action-research cycle during the maturing phase as described above.

Considering the theoretical framework of categorization of action-research cycles proposed by Mamlok-Naaman and Eilks (2012), G2's research process started as a practice action-research and evolved to an emancipatory mode, due to the development of innovative teaching practices, which were disseminated by the teachers involved in their development. Moreover, action-research promoted teachers' autonomy and changes in the teaching practices, as recognised in the literature (Borko, 2004).

Moving towards IMPG's *consequence domain*, under research question 2, the analysis showed that G2 developed a curriculum integrated field trip, contextualized in real word situations and combining diversified teaching strategies, such as learning of contextualized phenomena, debate in small groups or intentional questioning (Marques et al., 2015a). All of these were referred in the literature as effective science teaching strategies (e.g., Schroeder et al., 2007; Wise, 1996). Regarding the mobilized resources, the main ones were information and communication technologies, e.g., for presenting information, either by teacher and by pupils, or for reducing the novelty-space (Orion, 2007); several laboratory and outdoors instruments; and G2's fieldwork guide. The traditional blackboard and textbook were not frequently used, contrasting with other studies' results (e.g., Herbert et al., 2003). Considering IPEC's teachers teaching practices characterization, made at the beginning of the project (Marques et al., 2008), this analysis revealed an evolution of G2's teachers teaching strategies that was acknowledged by themselves (e.g., Morgado et al., 2008). Additionally, the development of a content analysis instrument for effective teaching strategies in SE allows educators aligning specific teaching strategies with indicators from meta-analytic studies (e.g., Schroeder et al., 2007). This instrument is also useful for science

teachers that which to diversify and adapt their set of teaching strategies, sustaining their options in literature recommendations.

Still in the consequence domain, the research question 3 prompted the analysis of the coherence of G2's teaching practices with innovation indicators for SE, present in the literature (Marques et al., 2011). In this study, empirical data was collected and linked to 13 out of 14 innovation descriptors in science teaching, supporting the claim that G2 developed challenging innovative practices (Adams, 2003). Moreover, other teachers from G2's schools got involved in this CoP practices. This contributes to sustaining the claim that innovation created by teachers can more easily be disseminated and adopted (Towndrow et al., 2010).

Finally, the literature review performed for research question 4 allowed identifying six CD principles. Crossing these with the empirical data revealed that G2 enacted all the principles:

- not centralized CD – in this CoP, the decision making was shared both by teachers and researchers, as well as with other teachers from the G2 teachers' schools and even some contributions from their students;
- CD flexible and differentiated – the definition of alternative teaching and learning sequences and the adaptation of the initial curricular module, to better fit each teacher educational context, were important features;
- CD contextualized in Science-Technology-Society-Environment – the curricular module is based on pupils' analysis and decision making regarding a controversial societal problem;
- Integrated CD – there is an explicit articulation of the academic subjects of Geology and Chemistry;
- CD with iterative phases – two cycles of action-research were identified;
- Reflexive CD – this was shown in previous related work (Cruz, 2010).

Considering the above presented, the participation in this online CoP originated a CD coherent with literature emerging principles, which was a relevant consequence for the teaching practices of G2 members. This study allowed to empirically validate a set of theoretical CD principles, as well as the literature-emergent analysis instrument (Marques et al., 2015b).

Conclusions and implications

In this case study, Clarke and Hollingsworth (2002) IMPG revealed to be useful for the understanding of the implications for the professional growth of teachers participating in an online CoP. Additionally, this study allowed to recognize some features for the adaptation of the model to this context (see Figure 4), which are explained in the following paragraphs.

Regarding the process leading to the development of a curricular module, the results were analysed considering two cycles of action-research. These contributed to the changing of teaching practices, in an emancipator way (Mamlok-Naaman & Eilks, 2012). In Figure 4, the changes in the analysed domains are represented, after triangulation with the members' views, which were disseminated in papers and communications. The adaptation of the IMPG to this online CoP context is a theoretical contribution of this work.

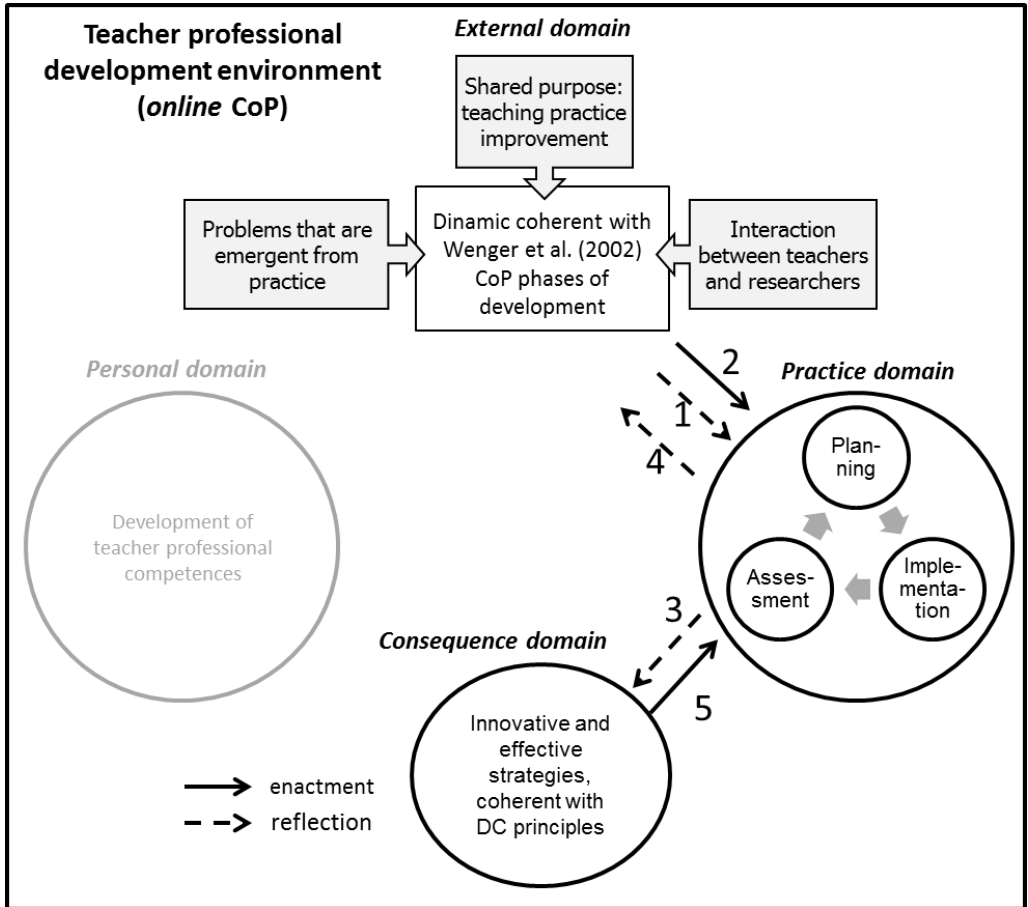


Figure 4. Adaptation of Clarke and Hollingsworth (2002) interconnected model of professional growth to the studied case

In this case study, the environment of professional growth or teacher PD, named changing environment by Clarke and Hollingsworth, is the online CoP formed under the IPEC project. The interaction dynamics established in this community are coherent with an adaptation of Wenger, McDermott, and Snyder (2002) model. It inclusively revealed a high variation in the levels of participation in the CoP activities, during a two-year collaboration period. Among the stimuli characterizing this teachers’ external domain are:

- the identification of problems emergent from the teachers’ practices (Marques et al., 2008), and hence, with high relevance for the teachers and attending their professional concerns;

- the continued interaction between science teachers and researchers in SE, in an online environment. This type of partnership is recommended in the literature (e.g., Kraayenoord, Honan, & Moni, 2011);
- the sharing of a common purpose – improving teaching practice (Marques et al., 2008; Wenger, 1998).

Reflection processes about, e.g., ideas and concepts discovered/revisited through academic readings on SE; teaching experiences; or the explanation of why some curricular decisions were made (as stated in, e.g., Morgado et al., 2008), induced changes (represented by arrow 1, in Figure 4) in the practice domain. In this manner, they lead to professional experimentation (represented by arrow 2) regarding planning CD processes (collectively, literature informed, and with distance communication tools); the implementation of new ways of teaching (new, at least for the teachers involved in the online CoP); and even the development of unusual assessment processes (Lucas & Vasconcelos, 2005). All of these occurred in a cycle of action-research (Altrichter et al., 1993) that lead to the development of the first version of the curricular module.

The reflective processes, on the curricular module's assessment results, induced changes in the consequence domain (represented by arrow 3). G2 members acknowledged the innovative character of the developed practices (Morgado et al., 2008). This study's results support G2's self-report, as it allowed identifying empirical evidence pointing to the development of innovative and effective teaching strategies, which are also coherent with CD principles from the literature. Simultaneously, the same reflective processes lead to changes in the external domain (represented by arrow 4) as the CoP's dynamics started including interactions with teachers from G2 teachers' schools, i.e., each G2 teacher was a disseminator of the curricular module, an innovation, in their own school community. Thus, the action-research process they undertaken acquired an emancipatory feature (Mamlok-Naaman & Eilks, 2012). Furthermore, the acknowledgment of the consequences valued by G2 members lead to the second action-research cycle, with contributes from their local group of teachers, involving more experimentation in the practice domain (represented by arrow 5).

Finally, the personal domain appears greyed in Figure 4, due to the fact that this case study focused in the identification of contributions of an online CoP of teachers and researchers to their professional growth at the teaching practice level. Further research should include the analysis of changes in the personal domain, as well as consider

other theoretical frameworks, such as activity theory (Engeström, 1999; Vygotsky, 1978).

At last, each one of the papers related to this synthesis effort present a set of lessons learned. Here, we highlight the following recommendations to enhance the contributions of online CoP of teachers and researchers in SE to the teaching practices:

- expect participations peaks in the community activities and act accordingly, e.g., by promoting member's interactions in critical periods;
- value teachers' contributions, increasing their confidence in their ability to participate;
- avoid deadlines close to the end of the terms, when Portuguese teachers seem to be submitted to higher workload – similar limitations have been reported before (Pereira, 2007), but not at this level of detail;
- propose the development of cycles of action-research of the emancipatory type (Mamlok-Naaman & Eilks, 2012).
- support teachers in the theoretical clarification of teaching strategy (Leite, 2010);
- support teachers in the broadening of their teaching strategies repertoire;
- support teachers in the development of innovative challenging teaching practices (Towndrow et al., 2010), instead of innovations imposed by, e.g., the government (Aubusson, 2002).

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Annex I – Q1's content analysis framework

Analysis framework of the stages of development of an online CoP involving teachers and researchers in SE. The features that are not part of Wenger and colleagues' CoP life cycle are highlighted in bold.

Stages of development	Some typical activities in CoP involving teachers and researchers	Cycles of action-research
Potential	<p>Tension: balancing discovery and imagination. Teachers and/or researchers of a loose network find a potentially common interest in a domain: to promote student and teacher learning. Discovery of similar educational problems, the sharing of a passion and the possibility of professional development.</p> <p>Awareness of the value of the community. Negotiation of the educational topic (domain) and engaging issues, e.g., through the definition of a work plan.</p> <p>Identification with some members within the larger group, e.g., defining work groups.</p> <p>Exploration of the community's facilities (available or in development), e.g., an online platform with several communication tools.</p> <p>Giving/receiving technical support, e.g., asking for orientation related to the use of an online communication tool.</p>	<p>Identification of problems that emerge from practices</p> <p>Reflection</p>
Coalescing	<p>Tension: balancing incubating community and delivering immediate value.</p> <p>Improvement of the community's relationships and trust, e.g., through face-to-face meetings. Official launch of the community through community events. Discussion of group's norms.</p> <p>Delivering immediate value by negotiating what knowledge is useful to be shared and how to share it, e.g., to share literature references on education, to share teaching experiences, to discuss educational concepts, etc. Development of deep knowledge on the individual practice of each other.</p> <p>Awareness that colleagues are resources for learning.</p> <p>Involvement in group's discussions.</p> <p>Giving/receiving technical support, e.g., asking for orientation related to the use of an online communication tool.</p>	<p>Reflection (cont.)</p> <p>Planning</p> <p>Implementation</p> <p>Evaluation</p>
Maturing	<p>Tension: balancing the focus on the progression of the domain and the expansion of the community's membership and perspectives.</p> <p>Focus on developing a comprehensive corpus of knowledge and on cutting edge issues within the CoP's domain (organise, classify and identify gaps in the developed work) – higher demands of time and commitment.</p> <p>Expansion of the community's membership and perspectives.</p> <p>Disruption of the community's interaction, intimacy and</p>	<p>Evaluation (cont.)</p> <p>Reflection</p> <p>Planning</p> <p>Implementation</p> <p>Evaluation</p>

	domain. Common regulation of group's behaviour. Commitment to colleagues' growth. Growth of the community, through cycles of high and low energy.	
Stewardship	Ownership of the developed knowledge and practice, e.g., presenting the developed work in public. Building relationships with other communities. Open-mindedness (through accepting and soliciting) to new ideas and members, to keep the relevance. Tension: balancing ownership and open-mindedness.	Evaluation (cont.) Reflection Public presentation of the results
Transformation	Returning to a previous stage, conversing into a social group, division into different communities, merging with others or end of the CoP. Tension: balancing the let go of the community (fade away through the loss of its members) and the live on (remembering the community through its legacy). Possibility of returning to the community's facilities to access the built knowledge.	

Annex II – Q2's content analysis framework

Type of action enacted by the teachers (t) or the students (S) and its description

Type of action	Description of the action
Focus	The protagonist (T or S) defines and/or negotiates the learning objectives, orally or with the support of educational resources.
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.
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.
Questioning	The protagonist (T or S) raises questions orally or written, to be answered by S.
Debate	The protagonist (usually S), in interaction with other protagonists, analyses and orally exchanges ideas on a topic to reach a consensus.
Research and synthesis	The protagonist (usually S) collects information/data, processes it and synthesizes it, with the support of the needed educational resources.
Manipulating instruments	The protagonist (usually S) observes and interacts with laboratory or fieldwork instruments.

Frequency of action of the different actors

Protagonist of the action	Before Ñ (a)	Field trip Ñ (a)	After Ñ (a)	Total Ñ (a)
Teacher				
Individual student				
Students in small groups				
Teacher and students in the Class - shared protagonism				

Frequency of use of the different resources

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

Annex III – Q3's content analysis framework

Descriptors used posits that innovative SE teaching practices:

1. aims the acquisition/development of concepts, capacities, attitudes and values;
2. bases teaching on socio-constructivist perspectives – proposes the study of open problems;
3. bases teaching on socio-constructivist perspectives – promotes students' active participation;
4. bases teaching on socio-constructivist perspectives – promotes learning through the negotiation of meaning;
5. values a global perspective of science – connects information to real problems (STS contexts);
6. values a global perspective of science – promotes an interdisciplinary or a transdisciplinary approach to the content;
7. values a global perspective of science – promotes awareness of the dynamic nature of science;
8. teaches to different learning styles, e.g., through varied teaching methods, activities and materials;
9. propose synthesis activities and critical reflection;
10. gives unorthodox and unusual assignments;
11. modifies old teaching strategies and develops new (research-based) approaches;
12. encourages student feedback and reacts to it;
13. uses different methods of assessment, develops new and diverse student learning assessment tools and learning assessment includes concepts, capacities, attitudes and values;
14. evaluates the effectiveness of her/his innovative teaching method.