Critical Thinking with Online Communities of Practice and Learning in Teacher Education*

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Abstract

Communities of Practice and Learning (CPL), particularly those online, have been assuming a relevant role in teacher education [1,2]. Within this scope, one of the emerging purposes revolves around promoting the potential for critical thinking (CT) among future teachers, notably as a fundamental component for the development of scientifically and technologically literate citizens [3]. This is crucial, as teachers who themselves are critical thinkers tend to develop practices that encourage CT, creating multiple opportunities for students to mobilize critical thinking skills and valuing the development of critical thinking. Within this framework, over the past 14 years, an online CPL has been developed in various contexts, specifically within the curriculum of Science Didactics for Portuguese Elementary Education. The purpose of this proposal is to present the contributions of the online CPL in promoting CT. Methodologically, a description of this community and how it was fostered will be provided, aiming particularly to appeal to the CT abilities of graduate students. This is a mixed-method study. The data collected, for example, in interactions in different situations and contexts, such as discussion forums and autonomous work tasks proposed, including assessment, were subjected to content analysis. The results of the Cornell Critical Thinking Test (level X) were subjected to descriptive and inferential statistical analyses. Overall, the results consistently indicate improvement in the CT skills of future teachers. CPLs appear, therefore, in the context of Science Didactics education, as a facilitating pathway for promoting CT among future teachers of Elementary Education.

Keywords: *Online Communities of Practice and Learning (CPL); Critical Thinking; Teacher Education [Arial, 9-point, italics]*

1. Introduction

Teacher training has been a significant area of study and professional experience for various researchers, including the two authors of this document. Among its complex dimensions, one that has garnered significant interest and concern is the exploration of digital technologies in this training, maximizing their potential to promote critical thinking skills [1, 13].
At this level, online Continuing Professional Learning (CPL) has been increasingly recognized in the context of teacher training and in the promotion of critical thinking among future teachers, which is a fundamental component for developing scientifically and technologically literate citizens [3].
Given their role, Science teachers can enhance the scientific and technological literacy of current and future citizens. Therefore, they need scientific and technological training that prepares them for the changes of the 21st century, especially since we are now dealing with the first generation of children and pre-adolescents born in the era of digital tools, social networks, and Artificial Intelligence [3, 4].
This is crucial, as teachers who are themselves critical thinkers tend to develop practices that encourage critical thinking, creating multiple opportunities for students to mobilize critical thinking skills and value its development. Within this framework, over the past 14 years, an online CPL has been developed in various contexts, specifically within the curriculum of Science Didactics for Portuguese Elementary Education. The purpose of this proposal is to present the contributions of the online CPL in promoting critical thinking.

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2. Communities of Practice and Learning and Critical Thinking

Learning communities have been one of the avenues utilized for teacher training [2]. These communities have sought to integrate various innovations, particularly in the last decades of Digital Technologies. There are different types of communities with varied meanings, understandings, and functions, even when referring to teacher training, be it initial, continuing, or postgraduate [1].
As supported by various authors [e.g., 5], Communities of Practice (CoP) generally focus on sharing and (re)constructing skills and best practices for solving common problems or concerns. On the other hand, learning communities are spaces with explicit intentions and actions for developing learning in its various dimensions, where debate, sharing, and communicative construction of meanings for action occur [6]. These authors add that in teacher learning communities, joint work can be developed, for example, in planning teaching practices and in dialogue about teaching and learning. It is noteworthy that in online communities, members are already familiar with each other from the physical world, whereas in virtual communities, the individuals do not know each other physically and base their interactions on available Internet tools [1].
Online communities are increasingly used by teachers for professional, personal, social, guidance, and inspiration purposes, as they can offer authentic and personalized learning opportunities, configuring a setting close to a genuine ecological educational environment [7]. According to these authors, besides professionalism, these communities allow the development of various skills given the multiple interactions they provide.
Thus, from an integrative perspective, it is important to highlight that in these online communities, among other aspects:
(i) It is crucial to authentically address the difficulties, knowledge levels, motivations, and needs of the online community members; also considering the contexts where teachers work or will work [7];
(ii) More collaborative practices among teachers, including in the classroom, to enhance their students' learning, particularly their critical thinking skills [2, 13].
In summary, as noted by [1], online communities of practice and learning have primarily aimed to favor the sharing and (re)construction of skills for solving common problems, concerns, and difficulties, as well as socio-constructivist collaborative learning.
One of the skill areas that has become prominent in recent decades is critical thinking, which does not develop naturally and spontaneously, requiring gradual, systematic, and deliberate actions from the early years, with effects that tend to be lasting [4, 8]. There are many definitions of critical thinking, linked to different traditions, such as Philosophy, Education, and Psychology. Several definitions are based on the works developed by [9, 10] since the 1960s. For this author, critical thinking is a form of rational, reflective thinking focused on deciding what to believe or what to do, involving abilities (more linked to cognition) and dispositions (more to affectivity). As described in various publications, such as [11], dispositions can include using and mentioning credible sources, seeking alternatives, and being open-minded. Abilities include, for example, making and answering clarification and/or challenge questions; analyzing arguments; making and evaluating observations; making and evaluating inferences (deductive, inductive, and value judgments); deciding on an action; and interacting with others.
Based on this framework, its use in training and innovation, and the advances in studies conducted over the past 15 years, [3, 11] have developed a framework that includes, besides abilities and dispositions, other elements of critical thinking, such as knowledge (which also justifies the emphasis on the infusion approach) and norms to be applied to the thinking process to ensure its best quality. Examples of the former include scientific and technological theories and explanations, and of the latter, clarity, rigor, and impartiality.
As has been widely disseminated, [4] proposes the acronym PIGES to highlight the five attributes considered necessary for its promotion from the early years to adulthood, including in teacher training: Beginning as early as possible and from the early years; Intentionally, adopting a conceptualization for this purpose; Gradually and according to the learners' potential and contexts; Explicitly identifying the dimensions to be promoted; and Systematically throughout schooling and life.
In this perspective, and according to the same authors [11], the guidelines to enhance opportunities for intricate mobilization of knowledge, abilities, criteria/norms, and dispositions or attitudes/values of critical thinking, as in teacher training with CPL, are: (i) creating and sustaining a learning environment that encourages everyone to articulate their thoughts, test ideas or proposals, and confront their ideas with others'; (ii) giving students time to think and experiment for themselves; (iii) creating multiple opportunities for sharing, debating, and discussing based on productive questions, such as: "Can you

elaborate a bit more on the reasons for drawing that conclusion?" and (iv) managing participation and support and feedback to ensure progress in developing their various skills. The framework used is summarized in the following table, which was taken from [11]. This table identifies the dimensions involved in Critical (and Creative) Thinking, detailing the basic constituents.

Table 1. Identification of the Four Elements of Critical Thinking according to PIGES

Abilities	Dispositions or attitudes/values	Criteria/norms	Knowledge
Elementary Clarification, such as Summarizing, Identifying and Stating Reasons, Arguing	Open-mindedness	Clarity and Rigor	Scientific and Technological Theories and Explanations
Basic Support, such as Evaluating the Credibility of a Source and Making Observations	Seeking and Stating Reasons and Assuming Them Publicly	Precision considering the Situation as a Whole	History of Science and Technology (S&T)
Elaborate Clarification, such as Operationally Defining and Classifying	Using and Citing Credible Sources and Being Well-informed	Metacognition	Nature of Science and Critical Thinking (CT)
Inferences, such as Inductions and Making and Evaluating Value Judgments	Considering and Seeking Alternatives	Consistency and Coherence	Major Ideas and Concepts in S&T
Strategies and Tactics, such as Deciding and Interacting with Others, for example, to Present a Position to a Particular Audience Creativity, such as Originality, Flexibility, and Elaboration	Sensitivity to Others' Feelings, Knowledge Levels, and Degree of Elaboration Respect for Evidence Values such as Justice, Life, Truth, and Honesty	Systematicity Prudence and Inquiry Impartiality Planning and Strategy	Fields and Contexts of Current Research in S&T

Source: Tenreiro-Vieira e Vieira (2021)

3. Methodology and Findings

The study adopted a socio-critical or emancipatory paradigm, particularly pertinent to the training of future teachers, and employed a mixed-methods approach. The predominant design was action research, which is often associated with mixed-methods or multi-methodological research approaches characterized by being situational, interventionist, participatory, and self-evaluative. The primary aim was to focus on innovation and change. By continuously integrating research and action, the study aimed to transform the didactic training practices of future teachers to be explicitly and intentionally promotive of critical thinking (CT).

Participants included all future teachers enrolled in the Science Didactics course over a span of 14 years, totaling 76 Portuguese students with an average age of 21 years and 3 months. Of these, 71 voluntarily responded to the Cornell Critical Thinking Test (Level X).

The quantitative design involved a pre-test and post-test of students who took the Cornell Critical Thinking Test (Level X) [12]. This test was administered to the students twice: at the beginning of the semester (pre-test) and at the end (post-test), accessed digitally via the CPL. The test comprises 76 multiple-choice items organized into four parts, with an average completion time of 42 minutes. The test score is calculated by subtracting half the number of incorrect answers from the number of correct answers, as recommended by the test authors. SPSS software was used to obtain the main descriptive and inferential statistics.

Data collection techniques aimed at triangulating data included observation, document analysis, and testing. Qualitative data were gathered through observations made in the classroom context throughout the semester, focusing on students' reactions and interactions with each other and the teacher. Additionally, an analysis of the written work produced by future teachers within the scope of the didactic activities was conducted, as described in [1, 13]. These activities included debates, practical laboratory work, the creation of personal coats of arms, concept maps, and the writing of argumentative or position essays on socio-scientific issues.

Two online platforms were used in the CPL. For the first 8 years, the free Drupal platform was chosen, with technical support provided by STIC. The Community of Researchers and Teachers of Science

Education in Basic Education was created within this system. More recently, in the last six editions, MS Teams has been used. Both platforms were closed and primarily included students enrolled in the Science Didactics course.
The CPL was generally structured around posts following the "Welcome" message, with four main menus, tabs, or channels: Groups (each year's students had a closed group mainly for assessment tasks), Bibliography, Forums, Opinions/Studies, Students' Work, Feedback, and Other Communities. A Form was also included, which all students completed at the beginning of their registration in the CPL, called "Survey of Conceptions about Science Education/Didactics...", aimed at identifying the needs, doubts, and main difficulties of the master's students.
In the design and use of the CPL within the context of Science Didactics training, efforts were made to ensure that the formal attributes advocated for an online CPL were considered, such as addressing the needs, conceptions, and difficulties of the students. As noted in [1, 13], the course aimed to create a collaborative environment and promote a participative, open, constructive, and genuine culture.
Several proposed tasks, as described in [1], explicitly appealed to CT, such as the writing of position papers. Within the framework of formative and summative assessment, the instructor's feedback always included comments on the overall quality of the production and questions aimed at other CT capacities and dispositions, such as the FA2IA approach. Examples include: "What are the reasons given? Can you summarize?". This strategy intended to (i) encourage student participation and value their contributions; (ii) support students in articulating their own lines of thought, fostering interaction among community members; (iii) demonstrate flexibility and address each student's responses and questions throughout the semester; and (iv) promote dispositions such as open-mindedness, intellectual humility, honesty, cooperation, and respect.
Over the past six years, all interactions within the community were monitored and analyzed, as they were accessible to the administrator, the author of this publication. Given the nature of the data, content analysis was conducted, focusing on emerging patterns and regularities and interpreting them within the adopted theoretical framework [14]. All data obtained in the CPL referred to the work of [15] on the five levels of impact of professional development. This paper presents the first two levels: participants' reactions and their learning, particularly their CT.
The results of this study highlight that the initial interactions in the online CPL revealed incipient productions, with limited substantiation and few indications of CT capacity mobilization. Comments included issues such as lack of clarity, inaccuracies, and incomplete responses to the tasks. Regarding other CT dispositions and knowledge, students often appeared uninformed about the subjects under analysis and, in some cases, displayed a lack of open-mindedness. Similarly, the lack of rigor in oral and written academic discourse was frequently noted, including non-compliance with academic writing rules.
In the first 4 to 5 weeks of each academic year, when the online community in the Science Didactics course was active, a common denominator was observed: these and other dimensions/components of CT were scarcely evident. This was often acknowledged with comments like: "We are not used to these tasks and this level of rigor."
The formative process and, particularly, the instructor's feedback on each student's work appeared to progressively support the mobilization of CT, as students responded more effectively to the proposed tasks over time. These learning outcomes were evident in the CPL, especially in the students' responses to most of the CT-required tasks, with the most illustrative example being the clear stance in position papers and the credible reasons supporting their positions, cited in the text and with complete references.
Overall, a majority of students in each academic year began to challenge questions and request their peers to evaluate the credibility of sources used to support claims [1, 13]. These evidences point to learning in the context of their Science Didactics training through appropriate strategies, particularly questioning. At this level, approaches like FA2IA proved useful in formulating questions that integrated various proposed and developed activities, even those not directly involving written tasks, such as the creation of concept maps [1, 13]. The same applied to forums, such as the one following the presentation of the position paper on "The Use of Animals in Medical Research" in the online community.
Additionally, given the mixed nature of the study, the following table summarizes the statistics of the scores obtained by the 71 future teachers in the pre-test and post-test for CT, using the Cornell Critical Thinking Test (Level X).

Table 2. Descriptive Statistical Results Obtained in the Pre-test and Post-test for CT

Statistics	Pre-test	Post-test
Mean	36.90	45.98
Median	38.25	45.01
Standard Deviation	12.50	11.68
Variance	90.10	72.25
Minimum	18.50	28.00
Maximum	60.00	69.00

Observing the table, it is evident that the mean CT score in the post-test is higher than that obtained in the pre-test. The same trend is observed in the standard deviation, minimum, and maximum scores obtained at the end of the semester. Comparing the mean scores for CT, the t-test results were $t = 8.65$, $p < 0.002$, indicating a significantly higher mean CT score in the post-test than in the pre-test. These results align with previous findings and suggest that the training in Science Didactics and the participation in the PLC contributed to the improvement of CT in the future teachers. Throughout the semester, they demonstrated a progressive development of CT.

4. Conclusions and Implications

The study concludes that the course unit and the dynamics of the PLC contributed to the enhancement of CT among future teachers. Further research is needed on promoting CT in teacher training and the necessity of integrating it with other dimensions and areas of training. The intentional, continuous, systematic, and explicit effort to foster CT in this course unit throughout the semester, as advocated by PIGES, supports the positive results obtained.

The online PLC proved to be of great potential, especially due to the individual and collective memory constructed, particularly with the constructive, regulatory, and demanding feedback that was progressively achieved by the master's students.

One implication of this study is the necessity to combine efforts with other areas of teacher training to make the promotion of CT more effective, sustainable, and transferable to other contexts. Hence, there is a need to investigate whether these study participants, for example, promote CT among their students.

Another implication encourages continued investigation into the potential of PLCs, such as the online one used over 14 years, and to explore other strategies, activities, and resources for promoting CT and other professional, social, and personal competencies of future teachers. The results presented suggest that a better education for all is possible in a truly democratic society with ethical principles and respect for human rights [1].

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