education sciences

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Searching for Scientific Culture in Professional Development Programs for In-Service Teachers: Case of Latvia

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Abstract: Scientific culture in pedagogical work involves the integration of scientific principles, values, and practices into education to promote critical thinking, evidence-based reasoning, and curiosity. It fosters an environment where students develop as independent learners, problem-solvers, and informed citizens. Teachers play a key role in cultivating this culture, acting as facilitators and guides who equip students with the tools to think critically and engage with the world scientifically. While often associated with STEM disciplines, scientific literacy extends beyond these areas, emphasizing the integration of scientifically grounded knowledge into all subject areas. To achieve this, teachers must continually enhance their own understanding and skills in scientific thinking. Staying updated with the latest scientific discoveries, critically evaluating information, and applying innovative pedagogical methods are essential. Professional development can provide a vital avenue for teachers to acquire these competencies. Approaches such as reading scientific literature, collaborating with colleagues, and attending specialized training programs can improve teaching strategies and promote scientific thinking in the classroom. This study investigated professional development programs provided for in-service teachers to understand how they contribute to fostering a scientific culture. The researchers collected data from municipalities in Latvia and online resources to summarize the information on the professional development programs provided to in-service teachers. This study examined how elements of scientific culture are reflected in teacher professional development programs in Latvia, using Merton's CUDOS norms as an analytical framework. The acronym CUDOS refers to four foundational principles of scientific ethos: communalism, universalism, disinterestedness, and organized skepticism. These norms guided the evaluation of whether and how scientific inquiry values are embedded in the design and delivery of training programs for in-service teachers. Using quantitative and qualitative methods for data analysis, it was found that in-service teacher training in Latvia is highly eclectic and often lacks alignment with scientifically grounded principles. There are a lot of programs provided to develop transversal competencies, but very few subject-specific programs are available. The findings highlight the need for more structured and cohesive professional development programs to support in-service teachers in developing competence in cultivating scientific inquiry, nurturing curiosity, and empowering students to navigate an increasingly complex and technology-driven society. These insights offer practical implications for education policymakers and program designers aiming to enhance the scientific orientation of teacher training. By identifying specific gaps in content and alignment with scientific culture, this study provides an original contribution to the discourse on evidence-informed teacher development and supports a more conceptually grounded and equitable approach to lifelong professional learning in Latvia.

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Academic Editor: Eila Jeronen

Received: 8 March 2025
Revised: 17 June 2025
Accepted: 18 June 2025
Published: 19 June 2025

Citation: Daniela, L., & Zālīte-Supe, Z. (2025). Searching for Scientific Culture in Professional Development Programs for In-Service Teachers: Case of Latvia. *Education Sciences*, *15*(6), 784. https://doi.org/10.3390/educsci15060784

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Keywords: scientific culture; CUDOS norms; professional development; in-service teacher training

1. Introduction

Scientific culture in pedagogical work refers to the integration of scientific principles, values, and practices into teaching and learning processes. It encompasses fostering an environment where critical thinking, empirical reasoning, evidence-based approaches, and curiosity are prioritized in educational activities. This culture supports the development of students as independent learners, problem-solvers, and informed citizens (García-Carmona, 2023; Zimmerman & Klahr, 2018; Taylor et al., 2006). Teachers serve as facilitators, motivators, and guides, equipping learners with the skills and knowledge necessary to explore, analyze, and engage with the world scientifically. Scientific literacy is often associated with STEM disciplines, yet it holds broader significance, as scientifically grounded knowledge must also be integrated into other subject areas. To effectively convey the latest scientific insights and discoveries, teach students to think scientifically, support their innovative thinking, and guide it into a scientific framework, teachers themselves must continually enhance their competencies. This requires staying updated with the latest scientific findings, being able to critically evaluate information, and teaching students to do the same. Teachers can improve their competence in supporting scientific culture through various approaches, such as reading the current scientific literature, learning from colleagues, and participating in professional development (Āboltiņa et al., 2024; Kampmane et al., 2023; Darling-Hammond et al., 2017). Scientific culture is closely interrelated with scientific inquiry, which is built upon a set of principles, values, norms, and practices that underpin scientific progress and its application in society. Thomas Kuhn's ideas about the structure and development of scientific knowledge, particularly from his seminal work *The Structure of Scientific Revolutions* (Kuhn, 1962), can be interpreted within the context of general education to inform how a culture of scientific inquiry is cultivated. His concepts of paradigms, normal science, and paradigm shifts offer valuable frameworks for understanding and teaching science in schools (Kuhn, 1962, 1997), and the same ideas have been expressed in the work of Silitonga et al. (2020). Teachers play a crucial role in fostering this culture within educational environments, as they are responsible for instilling these values in their students, and they are instrumental in cultivating skepticism and critical thinking among students. For teachers to inspire innovation and a commitment to lifelong learning in their students, they must first embody these qualities themselves. To effectively do so, teachers themselves must engage in continuous professional development, equipping them with the necessary tools and knowledge to model and teach the principles of scientific inquiry to ensure their teaching is rooted in credible, evidence-based principles. By teaching students to ask questions, seek evidence, and critically evaluate assumptions, teachers lay the foundation for a scientific mindset. Professional development programs help teachers enhance these skills, enabling them to create a classroom culture that values inquiry and critical analysis. Teachers must lead by example in promoting an evidence-based approach. This means grounding classroom discussions and practices in empirical data rather than opinions or assumptions. Professional development programs can help in-service teachers understand how to integrate these practices into their teaching, ensuring students learn the value of reproducibility and accountability in scientific endeavors. Professional development can support this by keeping teachers updated on new discoveries, technologies, and teaching methods. This ongoing learning allows teachers to create dynamic and forward-thinking educational experiences. Even a long

time ago, Popper and Kuhn emphasized that scientific knowledge is not absolute or final (Popper, 1979; Kuhn, 1962, 1997). They both acknowledged that theories could change or be replaced over time as new evidence and perspectives emerge. Although this was acknowledged a long time ago, nowadays the same principles should be followed to ensure a scientific culture. Teachers' ability to instill its principles—such as skepticism, evidence-based thinking, ethics, and collaboration—depends on their own professional growth and learning. Antonio and Prudente (2024) have established that inquiry-based approaches have a profoundly positive impact on students' higher-order thinking skills, with an overall weighted effect size of g = 0.893, indicating a significant effect. The analysis of moderating factors reveals that the benefits of this approach are consistent across various educational levels, scientific disciplines, and degrees of inquiry implementation, demonstrating that incorporating inquiry-based methods into teaching scientific concepts effectively enhances students' ability to think critically and analytically. Professional development programs are, therefore, essential, as they can provide teachers with the tools, knowledge, and inspiration needed to model and teach these values effectively. Although professional development in education has been the subject of numerous studies, there remains a significant gap in understanding the extent to which scientific inquiry principles are adopted and consistently applied across STEM and non-STEM teacher training programs in Latvia. Despite the theoretical relevance of Merton's CUDOS norms, empirical studies assessing their presence in teacher professional development curricula are scarce, and the methodological clarity and validation process for identifying indicators of scientific culture in program summaries remain underexplored.

In this study, the concept of *inquiry-based methods* refers to pedagogical approaches that engage learners in asking questions, conducting investigations, analyzing evidence, and constructing knowledge through critical thinking and reflection. These methods are understood as a key operational expression of *scientific inquiry*, which is itself a core element of *scientific culture*. While *scientific culture* encompasses the broader values, norms, and attitudes that support evidence-based reasoning and openness to critical examination, *evidence-based approaches* refer more specifically to instructional practices informed by empirical research. Although these terms are interrelated and sometimes overlap, this study uses them with these distinctions in mind to analyze how teacher professional development programs contribute to fostering a scientifically grounded teaching environment.

The central **research question** guiding this study is: *To what extent do professional development programs offered to in-service teachers in Latvia reflect the principles of scientific culture, as defined by Merton's CUDOS norms?*

The **aim** of this study is to analyze the content and structure of professional development offerings for teachers and assess their alignment with scientific culture values. This includes identifying potential gaps, imbalances between STEM and non-STEM fields, and the prominence of transversal vs. subject-specific training.

The **significance** of this study lies in its contribution to both theory and practice. Theoretically, it extends the application of sociological and epistemological frameworks to the field of teacher education. Practically, it provides education stakeholders—particularly program designers and policymakers—with evidence-based insights on how to strengthen the scientific orientation of professional development and better prepare teachers to foster critical thinking, evidence-based reasoning, and scientific curiosity in their classrooms.

The exploration and development of the concept of a scientific culture and a culture of scientific inquiry encompasses several disciplines, including the philosophy of science, sociology, history, and psychology. Consequently, the key scholars in this field come from diverse backgrounds and have contributed to shaping the understanding, culture, and practices of science. Popper's emphasis on critical rationalism and the role of falsifiability

has influenced education systems worldwide (Popper, 1979). His principles encourage teachers and students to engage in rigorous questioning, evidence-based reasoning, and a commitment to openness and transparency—all central to fostering a scientific culture in schools. His work offers a robust framework for developing a culture of scientific inquiry that is vital for modern education. By incorporating principles such as iterative learning, objectivity, skepticism, humility, and collaboration, educators can create learning environments that reflect the essence of scientific culture. Popper's insights provide both a philosophical foundation and practical guidance for schools to prepare students to navigate and contribute to a science-driven world. For teachers, professional development informed by these principles becomes indispensable, ensuring that they are equipped to inspire and lead the next generation of critical thinkers and innovators. Another philosopher, Feyerabend, had a bit different approach, and his central thesis was that there is no single, fixed methodology that guarantees scientific progress. He argued that adhering strictly to a standardized scientific method could hinder creativity and innovation. Instead, Feyerabend advocated for "epistemological anarchism," the idea that "anything goes" in the pursuit of scientific knowledge, which reflected his belief that there is no single, universally valid method for conducting science. He argued that scientific progress often results from the use of diverse, unconventional, and even contradictory approaches. According to this view, **methodological pluralism**—rather than strict adherence to a fixed scientific method—encourages innovation, flexibility, and openness in scientific inquiry. This does not imply a lack of rigor but rather emphasizes a flexibility and openness to diverse methods and perspectives. According to Feyerabend, scientific advancement often occurs through unconventional means, including practices that defy traditional scientific norms (Feyerabend, 2020).

Popper's approach is grounded in critical rationalism and emphasizes **falsifiability** as the hallmark of scientific theories. His work offers a **robust and structured framework** for cultivating scientific inquiry through systematic criticism, logical reasoning, and rigorous testing. This makes his model particularly applicable to educational contexts where the goal is to foster structured, critical thinking and evidence-based learning processes.

In contrast, **Feyerabend's central thesis** challenges the idea of a universal scientific method. He argued that **no single, fixed methodology guarantees scientific progress**, and instead proposes *epistemological anarchism*—a pluralistic view that emphasizes flexibility, methodological diversity, and context-sensitive approaches. His perspective suggests that scientific breakthroughs often result from **non-traditional or even contradictory methods**, and that openness means allowing room for creative, unconventional inquiry.

While both perspectives value openness, **Popper's model focuses on discipline through criticism**, whereas **Feyerabend emphasizes freedom through methodological pluralism**. This distinction is important for understanding the range of theoretical approaches to scientific culture and their implications for designing teacher development programs.

Regardless of the approach used to foster a culture of scientific thinking, it is essential to recognize that students' higher-order thinking skills can be developed by promoting scientific inquiry. This implies that even when we remain open to new ideas, we must approach them scientifically, analyzing information critically and rigorously evaluating all claims to ensure their validity. By embedding this mindset into educational practices, we not only encourage innovation but also uphold the principles of evidence-based reasoning and critical analysis.

The concept of a scientific culture has undergone significant transformation over time, particularly in its application to the education sector. Maxera and Álvarez-Blanco (2022), in their work "*Scientific Culture and Education Sector: Literacy, Understanding, or Engagement?*", examined this evolution through three paradigms: **scientific literacy, public understand-**

ing of science, and **public engagement**. Each paradigm represents a distinct perspective on how scientific knowledge and practices can be integrated into education, and together, they offer a comprehensive framework for fostering scientific culture in schools and society. However, Maxera and Álvarez-Blanco pointed out that this paradigm has limitations. By emphasizing factual knowledge, it risks overlooking the broader cultural, ethical, and societal dimensions of science. For example, a student may understand the mechanics of climate change but lack the ability to critically evaluate policies or advocate for sustainable practices. Furthermore, the authors highlighted the importance of interdisciplinary approaches in overcoming the paradigm's limitations. Integrating science education with subjects such as history, social studies, and philosophy encourages students to see science as part of a larger human endeavor. This approach not only deepens their understanding but also empowers them to apply their knowledge to solve real-world problems (Liu et al., 2023; You, 2017).

Another aspect that should be taken into account is Robert K. Merton's influential theories, such as the Mertonian norms of science and his exploration of the social organization of science. Merton has profoundly shaped how we conceptualize the culture of scientific progress, but one of Merton's most enduring contributions is his articulation of the four norms of science. Robert K. Merton's CUDOS norms conceptualize the values that define scientific culture. These norms describe the ethical and epistemological principles that underpin scientific practice and include the following: communalism—the open sharing of knowledge among scientists, emphasizing the sharing of knowledge as a collective good; universalism—the evaluation of knowledge based on impersonal criteria, which asserts that scientific claims should be judged independently of the scientist's personal attributes; disinterestedness—the expectation that scientists act for the benefit of the community rather than personal gain and calls for objectivity and impartiality in the pursuit of knowledge; and organized skepticism—encourages the critical scrutiny of all claims. Together, these norms establish the ideals of a scientific culture, fostering a community committed to rigorous and unbiased inquiry (1973). Merton's norms illustrate how critical thinking functions within a scientific culture, while also serving as an entry point into scientific thinking. Critical thinking is not exclusive to scientists; rather, it should be a fundamental practice for all students and individuals across disciplines. Ponce de Leon (2025) applied Merton's norms in tertiary-level education, using them as a tool to show that critical thinking extends beyond the classroom. It is not just a skill for academic settings but a cultural practice that encourages self-reflection and continuous improvement. Andersen sought to enrich the conceptual basis of Merton's CUDOS norms, highlighting the role of free argumentative dialogue in upholding the integrity and progress of scientific inquiry (Andersen, 2024). However, as noted by philosophers like Popper (1979) and Kuhn (1962, 1997), the nature of scientific knowledge is not absolute and evolves with new discoveries. Therefore, it is imperative for educators to continually update their understanding of scientific principles, as teachers play a pivotal role in ensuring that scientific culture is integrated across various subjects and made accessible to all students, regardless of their parents' understanding of science.

While various conceptualizations of scientific culture—such as those proposed by Popper, Feyerabend, and Maxera & Álvarez-Blanco—highlight the philosophical and societal dimensions of scientific inquiry, Merton's CUDOS norms offer a structured and operationalizable framework. These norms (communalism, universalism, disinterestedness, and organized skepticism) capture the ethical and epistemological values of science in a way that is directly applicable to the analysis of educational content. In this study, CUDOS is used as the primary analytical lens because it enables a systematic evaluation of how core scientific principles are embedded in professional development programs for teachers.

This approach ensures both theoretical coherence and methodological clarity in assessing the presence of scientific culture in education.

2. Professional Development of Teachers

Engaging in regular professional development enables teachers to stay abreast of the latest advancements, ensuring they can effectively impart current scientific knowledge and foster a dynamic learning environment. By participating in well-structured training programs, in-service teachers can stay updated on the latest pedagogical advancements, refine their teaching techniques, and ensure that they are equipped to foster critical thinking and problem-solving skills in their students. This not only benefits the learners but also contributes to a dynamic and progressive educational environment (Daly-Lesch, 2019). A recent study underscored the importance of professional development in science education, highlighting that ongoing training enhances teachers' content knowledge and pedagogical skills, which in turn positively impact student achievement (Tang et al., 2022; Visvizi et al., 2018; Linde et al., 2023). Research has demonstrated that such methods significantly boost students' higher-order thinking skills, regardless of their educational level, discipline, or the degree of inquiry applied. For teachers to effectively implement these strategies, continuous professional development is crucial in helping them foster scientific inquiry, and it plays a crucial role in enhancing the quality of education, particularly through the adoption of innovative teaching approaches like inquiry-based learning. Darling-Hammond et al. (2017) identified five essential elements of effective professional development: content focus, emphasizing subject-specific pedagogy and deep knowledge; active learning, involving hands-on, practical experiences; coherence, aligning with teachers' knowledge and school curricula; duration, ensuring sustained support and practice; and collective participation, fostering collaboration among educators. These features make professional development more impactful, equipping teachers to inspire critical thinking and scientific engagement in students, ultimately promoting a robust scientific culture in education (Darling-Hammond et al., 2017; Kaulēns, 2022; Nīmante et al., 2025).

Recent studies have underscored the importance of professional development for teachers in fostering a scientific culture within educational settings. These studies highlight the need for professional development programs that enhance teachers' abilities to facilitate scientific argumentation, critical thinking, and inquiry-based learning. Professional development plays a pivotal role in equipping teachers with the skills necessary to foster a culture of scientific inquiry in their classrooms. A systematic review conducted by Wess et al. (2023) explored the design and effectiveness of professional development programs aimed at enhancing teachers' abilities to facilitate scientific argumentation. The findings of this review highlighted several critical components that contribute to the success of such programs. One of the most significant aspects identified was the inclusion of active learning opportunities. These opportunities immerse teachers in activities that mirror the processes of argumentation that they are expected to implement with their students. By actively engaging in these processes, teachers gain firsthand experience and practical insights into the challenges and strategies involved in fostering argumentation. This experiential approach ensures that the theoretical principles of argumentation are grounded in practical, classroom-relevant contexts. The study also emphasized the importance of a strong content focus in professional development programs. Effective programs provide teachers with deep insights into the subject matter and the pedagogical strategies necessary for teaching scientific argumentation. This dual focus ensures that teachers are not only well-versed in the content they are teaching but also adept at designing and facilitating activities that encourage students to engage in critical reasoning and evidence-based discussions (Wess et al., 2023). There is a significant body of research on fostering scientific inquiry within

professional development programs for STEM teachers, given the critical role that science, technology, engineering, and mathematics play in education. These studies often focus on strategies to enhance STEM teachers' understanding of inquiry-based methods, self-efficacy, and classroom implementation of scientific thinking. However, comparatively fewer studies and articles address the application of scientific inquiry principles to teachers in non-STEM fields, such as the humanities, arts, and social sciences. Research suggests that active learning techniques, when thoughtfully implemented, can effectively enhance scientific understanding among non-STEM majors in large classroom settings (Jin & Bierma, 2013). Adapting these principles requires highlighting the nature of scientific knowledge, which emphasizes how knowledge is constructed. For example, history lessons can involve critical analysis of primary sources (Williams & Rudge, 2019; Heering & Cavicchi, 2020), while arts education can encourage iterative creative processes similar to hypothesis testing (Braund & Reiss, 2019; Leite et al., 2024). Frameworks like the Next Generation Science Standards provide crosscutting concepts, such as "cause and effect," that non-STEM teachers can use to integrate inquiry-based methods into their subjects. Inquiry-based activities, such as collaborative research projects, help students in diverse fields explore real-world questions, fostering critical thinking and evidence-based reasoning. Reflection is crucial; teachers must guide students in understanding how knowledge evolves and encourage discussions on disciplinary methods. Professional development is key to equipping not only STEM teachers but also non-STEM educators with the tools to adapt inquiry approaches to their subjects. Although challenges exist, such as aligning inquiry methods with non-empirical disciplines, the effort to incorporate scientific inquiry across all fields enriches education. By leveraging inquiry's principles, teachers can inspire critical thinking and prepare students to tackle complex issues with a reflective and informed perspective (Lederman, 2019) and reach higher-order thinking skills (Sapriati et al., 2024). In this study, 'non-STEM' refers to subject areas outside science, technology, engineering, and mathematics, but does not imply that these disciplines lack empirical foundations or rigorous inquiry.

The reviewed literature provides a multifaceted understanding of scientific culture, drawing from philosophical, sociological, and educational perspectives. The insights of Popper, Feyerabend, and Merton, alongside contemporary frameworks, such as those proposed by Maxera and Álvarez-Blanco, illustrate the diverse conceptualizations of scientific inquiry and its role in education. These theoretical positions inform the present study by offering both normative and practical dimensions for analyzing teacher professional development. In particular, Merton's CUDOS norms are used as an analytical framework due to their clarity and applicability in identifying how scientific values are embedded in training programs. Based on this conceptual foundation, the aim of this study is to investigate how elements of scientific culture—especially those related to scientific inquiry—are represented in the content and structure of professional development opportunities provided for in-service teachers in Latvia.

3. Research Context

This study on researching scientific culture in professional development programs available to in-service teachers is part of the research activities conducted within the framework of the project *"Scientific School Culture for Sustainable Society"* (No.lzp-2021/1-0135). In this part of the research project, we analyzed the available information on professional development programs for in-service teachers across Latvia.

The professional development of teachers is governed by the Cabinet of Ministers (Cabinet of Ministers of the Republic of Latvia, 2018) Regulation No. 569 (*Regulations on the*

Education and Professional Qualifications Required for Teachers and the Procedure for Improving Teachers' Professional Competence), according to the following regulations:

- Professional competence of teachers must be improved by completing a program of at least 36 h over a three-year period, planned in cooperation with the head of the educational institution where the individual carries out their teaching activities.
- Professional competence development programs are designed and implemented by municipalities, private educational institutions, or non-governmental professional organizations for teachers, provided that their governing documents specify the improvement of teachers' professional competence. These programs must be approved by the municipality within whose administrative territory they are implemented, as stipulated in Cabinet of Ministers Regulation No. 569 (*Regulations on the Education and Professional Qualifications Required for Teachers and the Procedure for Improving Teachers' Professional Competence*).

Teachers can allocate a small portion of these 36 h to activities of their own choice, but the majority of the professional development must be completed through an accredited program approved by the respective municipality. It is mandated that each municipality is responsible for ensuring the professional competence development of educators, leading to the establishment of local procedures for program approval. However, there is no unified national system specifying how these approvals should be carried out, what documents are required for program accreditation, or the quality criteria for program content and instructors.

In Latvia, there are no defined guidelines regarding the formats of professional development activities (e.g., in-person, blended, remote, synchronous, or asynchronous learning) or the proportion in which teachers may participate in each format. Additionally, there are no specific requirements for the content of professional development programs—whether they should align with the subjects a teacher teaches in school or whether all professional development hours can be devoted to acquiring transversal competencies, because effective professional development should maintain a balance between transversal and subject-specific content, particularly when the goal is to cultivate evidence-based reasoning, critical thinking, and subject mastery, which are core aspects of scientific culture. If there is no balance, as a result, situations may arise where teachers develop their professional competence in a direction that has no relevance to their subject-specific teaching expertise or professional responsibilities. This lack of regulation can lead to inconsistencies in the quality and relevance of professional development activities across the education system, allowing a space for interpretation on the content of such courses, and leaving quality control solely to program providers. Municipalities are also permitted to procure programs from various organizations to offer them to in-service teachers, and a significant number of municipalities exercise this option. This decentralized approach, while offering flexibility and reducing bureaucracy, poses a risk that professional development programs may lose quality and fail to provide adequate support for enhancing teachers' scientific culture.

In this project, the culture of scientific inquiry is defined as a relatively stable set of norms, values, beliefs, and practices shaped and maintained through the interaction of individuals (teachers, educational leaders, students, and parents) and environmental factors (economic, social, political, cultural, legal, and historical) (García-Carmona, 2023; Zimmerman & Klahr, 2018; Indrašiene et al., 2021). The project employs an ecosystem approach (Charland, 2011), emphasizing that the scientific culture of schools should be assessed and promoted across the entire educational curriculum—not only in STEM subjects but also in language, social sciences, and arts education. Understanding and fostering a culture of scientific inquiry in secondary education can enhance science literacy levels

in society, stimulate students' interest in science, improve their understanding of it, and strengthen resilience against misinformation (Cross et al., 2020).

4. Research Design

This study focuses on professional development programs offered to in-service teachers as part of a larger research initiative analyzing the culture of scientific inquiry in Latvian schools. The researchers believe that professional development programs can enable teachers to acquire the latest scientifically grounded pedagogical methods, which in turn help to foster a culture of scientific thinking in schools by shaping attitudes, cultivating curiosity, and providing the tools for critical thinking to empower students.

To find the answer to the research question—to what extent do professional development programs offered to in-service teachers in Latvia reflect the principles of scientific culture, as defined by Merton's CUDOS norms, and align with effective professional development criteria defined by Hammond and colleagues—the researchers sought to gather information about professional development programs offered to in-service teachers in Latvia in 2023–2024 and analyze their content from a perspective of the possible development of a scientific culture. This study compiled data from municipalities regarding the professional development programs they provide and employed data mining methods to collect publicly available information on in-service teacher training programs online. The collected data were subsequently analyzed using both quantitative and qualitative approaches. The quantitative component allowed us to systematically map the presence and frequency of CUDOS-related elements across a broad range of program descriptions. This helped to identify general trends—such as the prevalence of transversal versus subject-specific training and the distribution of inquiry-oriented content between STEM and non-STEM fields.

The qualitative component involved a more detailed interpretive analysis of selected program descriptions. It allowed us to explore how the values of scientific culture—such as openness, critical thinking, or evidence-based reasoning—were expressed or implied in the language and design of the courses. Additionally, the reliability of the analysis was strengthened through a collaborative coding process: each author analyzed the program summaries independently, and the results were then compared. In cases where interpretations diverged, the researchers discussed their findings until a consensus was reached.

The two approaches are therefore complementary: the quantitative analysis gives us breadth and patterns, while the qualitative interpretation provides depth and context. Together, they offer a more nuanced and reliable response to the central research question, which examines the extent and nature of scientific culture integration in teacher professional development.

This study employed a descriptive research methodology, collecting and analyzing data on the professional development programs provided by municipalities for in-service teachers. To analyze the situation regarding in-service teacher professional development, we invited municipalities to provide information about the approved professional development programs offered to teachers and coordinated within their jurisdiction, as it is their duty to provide professional development for in-service teachers. The aim of this investigation was to understand the situation of professional development for in-service teachers and whether it aligns with understandings of scientific culture, and this research is a part of the project *Scientific Culture in Secondary Education*. In this project, we collect information on the use of scientific approaches in teaching, defining "scientific culture" as the utilization of scientifically grounded and evidence-based information in professional practice. This approach emphasizes that scientific culture should not only underpin STEM fields but should be foundational in every discipline.

Data were obtained using two approaches:

1. Municipalities were asked to complete a researcher-prepared questionnaire about their program offerings for in-service teachers.
2. A data mining method was applied to search for publicly available information online about professional development programs for in-service teachers.

The evaluation matrix was designed based on the theoretical constructs central to our research aim—namely, scientific culture and effective professional development. The items were developed deductively, drawing from two established frameworks:

I. Merton's CUDOS norms were used to identify indicators of scientific culture. Each item related to the principles, such as communalism, universalism, disinterestedness, and organized skepticism, enabled us to assess whether and how these values were represented in the analyzed content.
II. Darling-Hammond et al.'s (2017) criteria for effective professional development informed the evaluation of pedagogical quality, such as whether the program involved active learning, collaboration, content focus, and sustained support.

Together, these two frameworks offered complementary analytical lenses: CUDOS provided the epistemological and ethical grounding related to scientific thinking, while Darling-Hammond's model contextualized the pedagogical soundness and effectiveness of the training programs.

The evaluation matrix was piloted to ensure clarity and alignment with the frameworks and then used to structure the content analysis in a systematic and theory-informed way.

The data analysis included only those professional development programs that had received official confirmation from a municipality according to legislation in Latvia, ensuring that the programs were accepted as valid for enhancing in-service teachers' professional competence.

The data analyzed consisted solely of publicly available descriptions of professional development programs provided by municipalities and other professional development providers. No identifiable information about individual teachers or participants was collected or used.

Nevertheless, we maintained ethical standards in data handling by ensuring that all sources were properly cited, the information was used in accordance with its public availability, and the interpretations were presented respectfully and objectively.

As no human subjects were involved, formal ethical approval was not required under institutional guidelines for this type of research.

5. Scope of Data Compilation

The data compilation includes information on professional development programs offered by municipalities, as well as an analysis of various publicly available professional development programs for in-service teachers. However, the analysis does not include professional development programs offered by universities, as the researchers accepted the assumption that university-based programs are more scientifically grounded. This aspect will be addressed in the next phase of the study.

The initial data was analyzed quantitatively to understand the offerings of professional development programs. Subsequently, for those programs with accessible descriptions, a qualitative analysis of these descriptions was conducted based on the five essential elements of effective professional development identified by Darling-Hammond et al. (2017): content focus, emphasizing subject-specific pedagogy and deep knowledge; active learning, involving hands-on, practical experiences; coherence, aligning with teachers' knowledge

and school curricula; duration, ensuring sustained support and practice; and collective participation, fostering collaboration among educators. Another aspect analyzed was the scientific culture defined by Merton (1973) and known as CUDOS norms: communalism, universalism, disinterestedness, and organized skepticism, as these are norms which should be followed by scientists, and these are also accepted as valid for evaluating the development of the critical thinking of students (Ponce de Leon, 2025).

6. Results

During the period of research data collection (2023–2024), Latvia had 43 municipalities, which included 7 state cities and 36 districts. The number of municipalities was reduced from 119 in the year 2021. Some municipalities responded that they were unable to provide the requested information, citing various reasons. These included changes in municipal structure following administrative reforms in 2021, turnover of responsible personnel, changes in data tracking systems, or the fact that teachers independently search for professional development opportunities, and therefore, municipalities do not collect such data. Additionally, some municipalities indicated that the requested information is available on their websites and therefore saw no need to submit it to researchers. This variability highlighted challenges in centralizing and accessing data related to teacher professional development.

Below is a summary table of the information we asked municipalities to provide (see Table 1) and the results obtained from those municipalities (32 out of 43) that submitted data.

Table 1. Data collection from municipalities and results.

Indicator	Result
Name of the municipality	✔
Program title	✔
Brief description of the program	Provided for 11.4% of programs provided by municipalities
Program duration in hours	✔
Program instructor (name, surname)	Partially provided for 28.6%
Target audience	Partially provided for 47.2%
Program type (continuing education or professional development)	✔
Program format (in-person, remote, blended)	✔
Criteria for including the program in the municipal catalogue	Not provided

The table reflects both the data collection logic.

The results indicate that while most municipalities (32 from 43) were able to provide basic information, such as program titles, duration, and format, details about program descriptions, instructors, and target audiences were incomplete. No information was provided regarding the criteria used to include programs in the full offering for in-service teachers.

It can be concluded that municipalities lack a unified system for collecting data on available professional development programs and tracking the number of teachers who have participated in them. This has resulted in significant variation in how municipalities fulfill these responsibilities of providing professional development for in-service teachers. On one end of the spectrum, some municipalities have established clear and transparent procedures for offering professional development programs, including defined quality crite-

ria for program providers. On the other end, there are municipalities where no information is collected or organized, and any proposal to conduct a professional development program is approved without the establishment of specific quality standards. This inconsistency highlights the need for a standardized approach to ensure equitable access to high-quality professional development for all teachers all around the country.

7. Findings on Professional Development Programs Offered by Municipalities

A total of 1432 programs were identified across 32 out of 42 municipalities using a data mining method to search for accredited professional development programs. The average duration of a program is approximately 13.22 h, with the shortest program lasting 2 h and the longest spanning 360 h.

The criteria for including programs in professional development offerings for in-service teachers were not provided in 1283 cases. Where criteria were indicated (149 cases), the following categories were identified:

- **Pedagogical and professional development**: Enhancing teachers' professional and personal competencies.
- **Use of technology in education**: Developing digital skills and integrating technology into the teaching process.
- **Relevance to educational institutions and subject areas**: Aligning programs with specific subject areas or the needs of municipalities or educational institutions.
- **Target audience specificity**: Programs aimed at specific groups of teachers, such as primary or secondary school educators.
- **National and municipal policies**: Ensuring alignment with national or municipal education policies.
- **Relevance and innovation**: Focusing on current topics and innovations in education.
- **Quality and relevance of program content**: Emphasizing the quality, relevance, and goals of the program content.

Further analyses were performed for 149 professional development programs for which descriptions were provided. It is evident that most programs (70) are broadly targeted at teachers' transversal competence development rather than focusing on subject-specific teaching methodologies. Programs tailored to educators of specific subjects are offered significantly less frequently. This observation, combined with the distribution of program hours, suggests that less attention is given to subject-specific teaching methodologies (40) compared to broader topics covering transversal competencies that are applicable to all educators.

Unfortunately, the information about program content is very limited, making it difficult in many cases to determine what is being taught in the sessions and the rationale for including such programs in professional development offerings. According to the Cabinet of Ministers regulations, *"Regulations on the Education and Professional Qualifications Required for Teachers and the Procedure for Improving Teachers' Professional Competence"*, the development of professional competence programs must include a description of the program's goals, objectives, and expected outcomes, as well as the implementation method, target audience, execution plan (including the number of hours, planned topics, and their delivery methods), but this information is not provided to researchers. It can be concluded that the municipal officials responsible for approving the programs either did not adhere to these regulations, or the required information was submitted but not consolidated, and therefore not available to add to the data requested by researchers. This lack of systematic data collection hinders the creation of a general overview of program quality. However, the available information (or its absence) reveals several critical issues in the

provision of professional competence development for in-service teachers in municipalities. These include inconsistencies in regulatory compliance, a lack of transparency in program offerings, and challenges in evaluating the overall quality and relevance of the programs.

The data analyses allow us to conclude that the distribution of professional development programs offered to various groups in the education sector is very wide, and the content is very eclectic. Below are statistics on the target audience for whom programs were provided, and the numbers beside each category represent the number of programs offered for that specific group:

1. Teachers in educational institutions in general (544).
2. Preschool teachers (181).
3. Primary and secondary school teachers (145).
4. Teachers in educational institutions and other educational experts (113).
5. Primary school teachers (85).
6. Elementary school teachers (72).
7. Heads of educational institutions (72).
8. Inclusive education (72).
9. Out-of-school interest-based education (64).
10. Professional orientation education (52).
11. Preschool and elementary school (20).
12. Educational psychologists (4).
13. Foreign language (English) teachers (1).
14. Speech therapists (1).
15. Consulting teachers (1).
16. Technical staff in educational institutions (1).

Out of 1432 programs found through direct contact with municipalities and data mining, a total of 275 programs are organized in-person, 166 are conducted remotely, and 39 follow a blended learning format. However, there is no information available about the format of participation in 952 programs.

The program topics are highly diverse, and most are mentioned only once, which means that such topics are not popular among teachers. Below is a summary of the main themes, and in brackets, you can find the number of programs offered under a particular topic:

1. **Technology-related programs (298)**—Analysis was based on keywords such as digital, IT, information technology, software, hardware, computers, virtual reality, robotics, technology, and internet.
2. **Child rights protection (36)**—Analysis was based on keywords such as children, children's rights, and child rights protection.
3. **Programs reflecting routine pedagogical activities**—Several programs address topics that are part of teachers' regular daily work processes but are approved as professional development programs. This allows teachers to collect the required professional development hours by participating in programs that support the development of transversal competencies but are not subject-oriented. Examples include the following:
    - Communication methods for promoting self-directed learning in primary school.
    - End-of-school-year seminars.
    - Basic principles for providing behavior support in educational institutions.
    - Planning methodological work.
    - Effective lessons to support students' learning.
    - Experience-sharing sessions.

8. Analyses of Course Content

From the 1432 programs detected, information for only 110 programs on their content was available, and these programs were analyzed based on Darling-Hammond et al. (2017), identifying four (from five) essential elements of effective professional development, as the duration of the programs provided has already been analyzed quantitatively in previous research phase. Another aspect searched for from information on program content was indications of a scientific culture, as defined by Merton (1973), known as CUDOS norms. The last indicator included in the analyses was whether the program is subject-oriented or transversal-competence oriented. All the information was read by both authors, searching for these elements, and in the next step, both authors discussed their opinions to agree on the results. The defined and summarized information can be found in Table 2, where if the summary of the program content includes information about a specific indicator, it is coded as 'Yes.' If it is clearly evident that the program does not include the particular indicator, it is coded as 'No.' When the information provided indicates that there is only partial identification of this indicator, it is coded as 'Partly.' In cases where the available information does not allow for determining whether the indicator is detectable, it is coded as 'Not detectable.' Table 2 includes information about only 110 programs from the 1432 for which a summary of program content was provided by municipalities or found through data mining.

Table 2. Course content analyses.

Element	Number of Programs Containing Particular Element
Content focus, emphasizing subject-specific pedagogy and deep knowledge	Yes—40 No—70
Coherence, aligning with teachers' knowledge and school/preschool curricula	Yes—39 Partly—22 No—49
Collective participation, fostering collaboration among educators	Yes—56 No—8 Not detectable—46
Active learning, involving hands-on, practical experiences	Yes—65 No—1 Not detectable—44
Communalism *Communalism emphasizes the sharing of knowledge as a collective good*	Yes—82 No—7 Not detectable—21
Universalism *Universalism asserts that scientific claims should be judged independently of the scientist's personal attributes*	Yes—27 No—16 Not detectable—67
Disinterestedness *Disinterestedness calls for objectivity and impartiality in the pursuit of knowledge*	Yes—30 No—14 Not detectable—66
Organized skepticism *Organized skepticism encourages critical scrutiny of all claims*	Yes—24 No—15 Not detectable—71
Subject or transversal skills oriented	

Table 2. *Cont.*

Element	Number of Programs Containing Particular Element
Transversal skills	73
Digital competence in preschool	3
Digital competence in school	4
Arts/design and culture	12
STEM in preschool	2
STEM in school	6
Languages	1
Leadership	8
Sports	1
Literature	1

9. Discussion

The findings of this study offer a multidimensional perspective on the current state of professional development for in-service teachers in Latvia, particularly in relation to the integration of scientific culture and inquiry-based principles. While previous research has often highlighted the importance of developing transversal competencies (Kaulēns, 2022), this study demonstrates that such a focus—when not conceptually linked to pedagogical depth or evidence-based reasoning—risks fragmenting the purpose of professional learning.

Through an analysis of publicly available program descriptions and municipality-submitted data, it was evident that the structure and content of professional development courses are highly eclectic, inconsistent, and in many cases, insufficiently aligned with the principles of scientific culture. The application of Merton's CUDOS norms and Hammonds et al. criteria for effective professional development as an analytical framework allowed us to assess not only the presence of scientific values, such as universalism, communalism, disinterestedness, and organized skepticism, but also to evaluate how these principles are represented—or neglected—across diverse professional development contexts.

While communalism was more frequently reflected in the analyzed programs, particularly through collaborative and knowledge-sharing formats, other norms—especially organized skepticism—were scarcely detectable. This points to a significant gap in fostering critical thinking, a core competency required for scientific literacy and informed pedagogical practice. These results mirror Ponce de Leon's (2025) argument that without cultivating critical thinking through teacher development, the foundational ethos of scientific culture cannot be fully realized in classroom environments.

Moreover, the use of both quantitative and qualitative methods in this study revealed the limitations of a system that lacks national coherence in defining or monitoring professional development content. The decentralized structure allows municipalities considerable autonomy, which can encourage diversity but also results in disparities in the quality, focus, and scientific grounding of the programs. This study's mixed-methods approach helped bridge this fragmentation by not only identifying patterns in program types and participation formats but also by interpreting their epistemological and pedagogical implications.

Importantly, the results confirm that the issue is not simply the availability of professional development opportunities but their content, design, and relevance to evidence-based, inquiry-driven teaching. This concern is particularly acute in non-STEM fields, where connections to scientific inquiry are often either implicit or entirely absent. Yet, as outlined by Maxera and Álvarez-Blanco (2022), fostering a scientific culture in education requires interdisciplinary engagement, which this study found to be severely underrepresented.

The results indicate that teacher professional development in Latvia is highly eclectic, with offerings often failing to align fully with scientifically grounded principles. While these programs may have value for personal development or general well-being, their content often falls outside the scope of enhancing pedagogical skills, improving teaching methodologies, or developing scientific culture. Analyzing the course offerings against the professional development criteria set by Darling-Hammond et al. (2017) reveals that these criteria are only partially met. This poses a threat to the continuous professional development of teachers, which, in turn, may affect how they convey the latest scientific insights to students and foster the development of higher-order thinking skills. Other authors have already warned about this, as well (Al Shabibi et al., 2019; Hyde et al., 2025). This raises concerns about whether such offerings can contribute to the development of professional competence and support for scientific culture. The available content of the programs allows us to conclude that Merton's (1973) CUDOS norms can be found only in rare cases, and that the best situation is with communalism (detected in 82 cases), which emphasizes the sharing of knowledge as a collective good, but the worst situation is with organized skepticism, which is found only in 24 cases. This situation shows that critical thinking, which is the most important aspect for the development of scientific inquiry (García-Carmona, 2023; Zimmerman & Klahr, 2018; Indrašiene et al., 2021) and support of development of scientific culture (Maxera & Álvarez-Blanco, 2022), is not supported through professional development courses, confirming the conclusions from Ponce de Leon (2025) in her research that if we do not support the development of critical thinking we cannot fulfil CUDOS norms.

The professional development system in municipalities is very unclear and allows for various interpretations of what is considered to be professional development.

1. A large number of professional development courses of questionable quality are approved in municipalities, which, in essence, cannot be considered professional development. No monitoring is carried out for such courses.
2. A large number of courses are approved based only on their title, with no available information about their content. Very often, there is also no information about the course instructor.
3. The majority of professional development courses are not about teaching methodologies for a specific subject.
4. The analysis of professional development offerings indicates that they minimally meet the criteria for effective professional development defined by Darling-Hammond et al. (2017) and only to a small extent align with the CUDOS criteria defined by Merton (1973), which characterize scientific rigor in specific activities.

There is no unified system in the country for registering courses and collecting information, making it impossible to accurately track the types of courses teachers participate in. One might assume that teachers, as professionals, only engage in high-quality professional development courses. Considering that the majority of teachers have extensive teaching experience, meaning their professional knowledge may be outdated, it is critically important that professional development is truly professional.

The literature suggests that professional development programs in STEM fields more frequently incorporate structured approaches to inquiry-based learning, evidence use, and methodological transparency. This is consistent with international findings, where STEM disciplines are typically more aligned with explicit scientific reasoning frameworks.

Our research outcomes reflect a similar tendency in the Latvian context. The programs related to STEM subjects more often demonstrated alignment with CUDOS norms—particularly in the areas of communalism and universalism—while non-STEM courses tended to focus on transversal competencies or general pedagogical strategies,

without explicitly grounding them in scientific inquiry principles. This alignment reinforces the notion of an uneven integration of scientific culture across disciplines and highlights the need for a more systematic inclusion of inquiry-based approaches in non-STEM professional development programs, as well.

This discussion highlights the need for a systemic reconsideration of how professional development programs are conceptualized, accredited, and evaluated in Latvia. Beyond ensuring regulatory compliance, there is a pressing need to establish clear national quality criteria that include alignment with scientific culture, pedagogical coherence, and relevance to teaching practice. The findings thus carry implications not only for municipalities and program providers but also for policymakers, who must consider mechanisms for strengthening the scientific orientation of teacher education across all subject areas.

This study calls for a more coherent and scientifically grounded approach to the design and evaluation of professional development programs. It underscores the importance of policy-level frameworks that define not only structural requirements but also the conceptual orientation of teacher learning towards the values of a scientific culture.

10. Conclusions

This study set out to explore how professional development programs for in-service teachers in Latvia reflect the principles of scientific culture, as defined through Merton's CUDOS norms and the effective professional development criteria developed by Hammon et al., and to what extent they address the need for cultivating inquiry-based, evidence-informed teaching. The analysis reveals that while various courses are available across municipalities, there is a significant lack of conceptual and pedagogical coherence in how these programs engage with the fundamental values of scientific reasoning and culture.

This study addressed a clear research gap by systematically examining program descriptions and municipal offerings through the lens of scientific norms—an approach not previously applied in the Latvian context. By doing so, it contributes both empirically and methodologically to the discourse on teacher professional development, offering a novel analytical framework that allows for the assessment of not only what is taught but also how it aligns with broader scientific and educational values.

The research question—whether and how professional development programs incorporate elements of scientific culture and effective professional development—was addressed through a structured document analysis and synthesis of 32 programs. The findings indicate partial and inconsistent integration of CUDOS principles, with communalism being the most visible and organized skepticism the least. This highlights a gap between the stated goals of developing transversal competencies and the deeper epistemological foundations necessary for nurturing a scientific mindset in education.

Our research contributes to bridging this gap by providing an evidence-based mapping of how scientific culture is represented in in-service teacher training across disciplines.

By drawing attention to this imbalance and analyzing it through a structured theoretical lens, our study provides practical insights for policymakers and program designers who aim to foster scientific culture across all subject areas. We believe that these findings help initiate a more informed conversation on how to ensure equitable and conceptually coherent professional development for all teachers, regardless of their subject field.

Limitations—It must be acknowledged that the analysis of the program offerings has been conducted quantitatively, focusing on their availability, and qualitatively by examining publicly accessible information, such as program descriptions and the conditions for participation. However, the available data does not allow for an assessment of the quality of program delivery. In the next phases of this study, it will be necessary to conduct

an in-depth investigation into participants' experiences participating in such programs to gain a more comprehensive understanding of their impact and quality.

Author Contributions: Conceptualization, L.D.; methodology, L.D.; validation, L.D. and Z.Z.-S.; formal analysis, L.D. and Z.Z.-S.; investigation, L.D. and Z.Z.-S.; data curation, L.D. and Z.Z.-S.; writing— L.D. and Z.Z.-S.; writing—review and editing L.D. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by Latvian Council of Sciences (lzp-2021/1-0135).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data are available here—https://docs.google.com/spreadsheets/d/1Ue-llTBxDsyc_u1XdX2wg5wDHMywa1tsYGyzM4C-i8s/edit?usp=drive_link (accessed on 3 May 2025).

Conflicts of Interest: The authors declare no conflict of interest.

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