frontiers | Frontiers in Education

TYPE Curriculum, Instruction, and Pedagogy
PUBLISHED 03 December 2025
DOI 10.3389/feduc.2025.1611730

OPEN ACCESS

EDITED BY
Mary Frances Rice,
University of New Mexico, United States

REVIEWED BY
Semirhan Gökçe,
Niğde Ömer Halisdemir University, Türkiye
Majken Korsager,
University of Oslo, Norway

*CORRESPONDENCE
Catalina Lomos
✉ catalina.lomos@liser.lu

RECEIVED 14 April 2025
ACCEPTED 14 October 2025
PUBLISHED 03 December 2025

CITATION
Lomos C, Schaap H, Luyten JW, Kesting F, Lima da Cunha F, Frieseisen C, Telli S and Fowler S (2025) Professional learning communities to facilitate professional development for using digital technology in the classroom: a teacher-based program evaluation.
Front. Educ. 10:1611730.
doi: 10.3389/feduc.2025.1611730

Professional learning communities to facilitate professional development for using digital technology in the classroom: a teacher-based program evaluation

Catalina Lomos[1]*, Harmen Schaap[2], J. W. (Hans) Luyten[3], Frauke Kesting[4], Filipe Lima da Cunha[4], Carole Frieseisen[4], Sibel Telli[5] and Sam Fowler[6]

[1]Luxembourg Institute of Socio-Economic Research, Esch-sur-Alzette, Luxembourg, [2]Radboud Teachers Academy, Radboud University, Nijmegen, Netherlands, [3]Faculty of Behavioral, Management and Social Sciences, University of Twente, Enschede, Netherlands, [4]SCRIPT (Service de Coordination de la Recherche et de l'Innovation Pédagogiques et Technologiques), Ministry of Education, Luxembourg, Luxembourg, [5]Educational Consultancy & Professional Development (O&T), Faculty of Social and Behavioural Sciences, Utrecht University, Utrecht, Netherlands, [6]School of Education, University of South Australia, Adelaide, SA, Australia

This article presents a shift from traditional "technical" professional development (PD) to a PD of "praxis" and reflects on the benefits and barriers that this entails. Often, PD in digital technology is unsustainable because it provides simple tips or a few sample lessons that teachers are happy to deliver until the technology fails or becomes obsolete. PD in which teachers are actively engaged in exploring their own practice and understanding the rationale behind the implementation of technology is more likely to result in teachers who can adapt current technologies and reflect on the constraints they inherently present. Professional learning communities (PLCs), as a long-term support for PD, allow this to happen within the context of the school and its specific affordances. This article describes one such innovative PD program designed and developed by a team of one researcher and three teachers and implemented with 51 teachers from 10 primary schools in Luxembourg. The primary goal of the PD program was to support teachers in using a digital learning platform for mathematics in their classrooms. The secondary goal was to facilitate the emergence of PLCs within their schools, so that teachers could support each other in the long term. The format of the program was with and about technology, as it was also delivered online, with teachers meeting face-to-face and working together in their schools. The collaborative nature of the program—the fact that teachers had to set common goals for the training, design and plan collaborative activities, and reflect on how best to integrate the digital learning platform into their classroom practice—was the greatest benefit reported by teachers in all groups, and it increased over the six consecutive training sessions. Most teachers reported that the frequency of their use of the digital learning platform in the classroom increased and strongly increased as a result of the training. New designs for teacher PD with and about digital technologies can build on theories of effective teacher professional learning through PLCs and provide teachers with a safe and sustainable environment in their school for further practice and development.

KEYWORDS

professional development, digital technologies, professional learning communities, mathematics, primary education, technology adoption

Introduction

Professional development (PD) programs on emerging digital technologies (DT) are shifting their focus from providing a few sample lessons using the technology to supporting teachers in developing a shared, collaborative, and applied vision of expected practice. Such PD for, with, or about digital technologies (PD-DT), built on collaborative teacher practice, can have a positive impact on teachers' adoption and use of technology (Ni et al., 2021). More insight is needed into the benefits and barriers of organizing and implementing such PD-DTs, which aim to support teachers in collaboratively exploring their own practice with the technology as a means of professional learning (Lomos et al., 2023a).

Putting digital learning technologies into practice takes time, and teachers need various forms of support to make it work (Bidarian et al., 2011). Teachers need to consult with their colleagues and test the technology to determine what works best for them (Loogma et al., 2012). PD-DTs should be designed to create conditions in which teachers can actively engage in exploring their own practices with the technology and reflect on new discoveries and best practices together. PD-DTs must provide long-term and varied support that is available whenever teachers require it, especially as the technology evolves and presents unique challenges that were not anticipated during the PD-DT implementation.

One way to provide such sustained development opportunities is through professional learning communities (PLCs) (Lomos, 2012). This article presents and analyzes the specific outcomes of such PD-DT, as well as the direct feedback and reflections of the participating teachers. The primary goal of the PD-DT was to introduce teachers to a new digital learning platform for mathematics in primary education. The secondary goal was to develop each group of teachers in their school into a PLC. Each group in their school had to coordinate collaboratively its own learning experience, with a goal of moving from traditional "technical" PD to a PD of "praxis." The teachers met in their school as a group without a trainer and accessed the PD-DT online. This article presents the rationale, creative work, structure, and pedagogical principles behind this innovative program. More importantly, it addresses our objective of understanding how teachers perceived the program over time and answers our implicit research question:

> RQ: Which factors shaped teachers' reported benefits and barriers regarding the program?

Background for the educational innovation

The study focuses on the development of MathemaTIC, a digital learning platform for mathematics aimed at supporting and enriching the classroom practice of primary and secondary school students and teachers. MathemaTIC (2015)[1] is the digital learning platform developed in Luxembourg since 2015 and initially proposed to primary school teachers, who are the focus of this study. MathemaTIC was part of a national initiative in education called "Digital (4) Education" (MENJE, 2015), which aimed to develop specific student competencies, namely "digital worker, digital peer, digital citizen, digital entrepreneur, and digital learner."

MathemaTIC covers the national curriculum for primary and secondary mathematics and proposes more than 700 learning items to help students learn and practice mathematics. All these items are available in four languages, namely German, French, English and Portuguese, in line with the multilingual context of the educational system, through animations, instructional videos, written and spoken content. The most relevant feature for teachers is the "Teacher View," which provides them with the tools to see what students have done while working on the platform, which exercises they have completed, and their level of performance. With this knowledge, teachers can use the "Agenda" tool in the platform to assign specific tasks from a domain or with a specific level of difficulty to an individual or a group of students. In other words, the platform provides teachers with numerous tools and opportunities for individualized and differentiated learning, as well as for remediation and creative use.

Given the complexity of the digital learning environment and the many tools and activities that teachers could use, create, or assign in the platform, an extended PD program was designed and proposed to teachers in the adoption process, called "Professional Learning Communities for MathemaTIC" PLC for/fir Mathematic (2018),[2] as described below.

Pedagogical framework underlying the educational activity

Previous empirical evidence on teachers' technology adoption has introduced "the learning curve for new technology software"

1 https://mathematic.lu/

2 https://www.mathematic.lu/plc/

10.3389/feduc.2025.1611730

and "the technology adoption curve" (Aldunate and Nussbaum, 2013, p.520), models that indicate that, teachers, as adopters, need to invest significant time in discovering and using the technology until the benefits are visible in their classroom practice. Furthermore, the amount of time teachers invest in incorporating the technology into their classroom practice is positively related to the likelihood of adopting and using the new technology (Lomos et al., 2023b). The implication of these previous empirical findings is that teachers need long-term support to adopt new technologies into their practice, which is available when teachers face different entry and exit points or difficulties caused by the technology's complexity. Collaboration among teachers that is formally structured in schools, such as within PLCs, has the potential to support teachers in their adoption process (e.g., Chaseling et al., 2014; Donnelly et al., 2011; Lomos et al., 2023a,b; Loogma et al., 2012).

Professional communities: school-wide culture of collaboration

In the present study, we used the design principles of professional communities as a facilitator of teacher PD-DT aimed at enriching teachers' use of digital learning tools in their classroom practice. The term Professional Community (PC) was first defined in the United States (e.g., Hord, 1997; Little and McLaughlin, 1993; McLaughlin and Talbert, 2007; Siskin, 1994). Most of the quantitative studies that have operationalized and measured PC uniquely from other concepts of teacher collaboration have used five characteristics defined as follows:

(1) "Shared sense of purpose" refers to the extent to which teachers agree with the school's mission and its operating principles;
(2) "Collective responsibility for student learning" indicates teachers' mutual commitment to student success;
(3) "Deprivatization of practice" is the extent to which teachers observe each other's teaching for feedback purposes;
(4) "Collaborative activity" is a temporal measure of the extent to which teachers engage in collaborative practices; and
(5) "Reflective dialogue" refers to the extent to which teachers discuss specific pedagogical issues with each other on a professional basis.

(e.g., Bryk et al., 1999; Lee and Smith, 1996; Louis and Kruse, 1995; Louis et al., 1996; Louis and Marks, 1998; Newmann and Wehlage, 1995; Wiley, 2001; in Lomos, 2012).

However, our goal was to support teachers' professional learning by building on the characteristics of school-based PCs, ultimately aiming to create school-based professional learning communities. Participating teachers engaged in active learning in a collegial manner. This approach was not limited to "one-shot experiences," but rather extended over sustained periods of time and was supported by school management (Borko et al., 2010). Given the explicit focus on teacher learning processes supported by specific school conditions in this PD-DT, we convened and worked to create professional learning communities (PLCs) in schools guided by the definitions and operationalization of the PLC concept and format (e.g., Hord et al., 1999; Stoll and Louis, 2007).

However, participating in PLCs does not automatically result in changes to teachers' instruction. As Little (1990) cautions, whether such changes occur probably depends on the nature of teachers' collaboration. Kennedy (2016) emphasize that collegial collaboration can help teachers modify their classroom behavior, especially when the focus is on the issues and concerns arising from daily instruction. This is why PLC formats are increasingly used to enhance teacher collaboration, professional development, and school improvement.

Learning environment, learning objectives and pedagogical format

Building on the five characteristics of PCs, and with the explicit goal of teacher learning, the PD-DT was organized into six monthly sessions (starting with an introductory session) spread over an entire school year. These sessions were designed to take advantage of the many tools and activities that can be done in the MathemaTIC as shown in Figure 1a [see Lomos et al. (2025) for more details on the PD-DT design]. Each group of teachers at their respective schools collaborated to design their own learning experience, with the goal of transitioning from traditional "technical" PD to PD based on "praxis." The teachers met at their schools as a group without a trainer and accessed the PD-DT online on the Moodle platform, a widely used Learning Management System. The content, presented through videos and digital demonstrations, covered digital learning technology and PLC practices. During each session, the teachers completed two collaborative tasks that allowed them to practice and reflect on their work and the technology's specific applications.

The PD-DT had two goals. The first goal was to support the participating groups of teachers in developing into PLCs around the PD-DT. To this end, the six sessions focused on introducing and practicing the known dimensions of a PC (Figure 1a), while most of the time in the six sessions was spent on MathemaTIC applications (Figure 1c).

All sessions were designed, developed, and implemented by a team of one researcher and three teachers with experience or interest in digital learning in mathematics, as shown in Figure 2a. Over time, other collaborators joined the team, including master's students in education and other disciplines, who enriched and expanded the program's content [see the "Professional Learning Communities for MathemaTIC" PLC for/fir Mathematic (2018)[2] website for more information on all collaborators]. The team designed the activities and tasks from scratch and developed all the video materials (Figure 2b). These included instructional videos of us (Figure 1b) for the PLC portion and demonstration videos and ideas for lesson plans for the MathemaTIC portion (Figure 1d) [see Lomos et al. (2025) for more details on the PD-DT design].

In terms of Format, teachers had to attend each session as a PC in their school. The only way to follow the PD-DT was for a group of teachers to participate together, preferably all the teachers of a particular grade in the school. They had to decide when to meet and work together in the school for 1 h 30 min to complete one training session per month. The materials were provided on the national teacher-training institute's (IFEN) Moodle platform, a widely used Learning Management System (Figure 2c), and there was no on-site

10.3389/feduc.2025.1611730

FIGURE 1
The PLC for MathemaTIC program; **(a)** the organization into six sessions, with the first part of each session devoted to one of the five PC characteristics; **(b)** the format of the videos and materials for the PC part of the training; **(c)** the second part of each session devoted to the content and applications of MathemaTIC; **(d)** the format of the demonstration videos and lesson examples for MathemaTIC.

trainer. Teachers were required to take on assigned roles and follow a clear session structure.

Each session included two group work tasks, which provided opportunities for teachers to co-create knowledge and generate their own learning as a group, what we call in this study PD of "praxis." The results of these collaborative tasks – one PLC-related and one MathemaTIC-related task in each session – were uploaded to the Moodle platform, and teachers received detailed feedback from the team of trainers after each session (Figure 2d) and they were asked to reflect on the feedback at the beginning of each session. Based on their actual practice, shared sense of purpose for the training, and their reflection on the feedback, teachers were expected to develop new content knowledge and shared pedagogical knowledge (Mishra and Koehler, 2006) by finding the most effective and adapted way to integrate MathemaTIC into teaching and learning mathematics in their classrooms.

Processes and data

Data collection and data analysis

In order to know how well the program was being received, we collected data through a mix of open-ended and closed-ended questions posed to teachers individually via an online form after each of the six sessions over the course of a school year. The results report the benefits and barriers that teachers perceived as part the six-sessions PD-DT.

A total of 51 teachers from 10 schools in Luxembourg voluntarily signed up online to participate in the PD program. The PD-DT and implicitly the study were communicated to all primary schools in Luxembourg by means of a brochure and a public website (see text footnote 2).

29 teachers from 6 schools attended all 6 sessions and completed all individual and group tasks, and their anonymous data were analyzed for this study. Not included in this study are the 16 teachers from 4 schools and 6 teachers across the remaining schools who dropped out of the PD mostly after the first session. The main reason reported for dropping out was that the PD-DT did not meet their expectations, especially in terms of the content and focus of the PD (i.e., PLC characteristics or MathemaTIC).

We used thematic analysis (Braun and Clarke, 2006) to analyze the teachers' responses to the open-ended questions asked at the end of each of the six sessions (see the Supplementary Material for the exact questions). The questions asked the teachers about their impressions of the session and their overall satisfaction with the training. We developed a coding scheme (see the Supplementary Material for the complete coding scheme) based on theoretical considerations and the specific characteristics and goals of the training. We coded the responses on three levels of interest, in

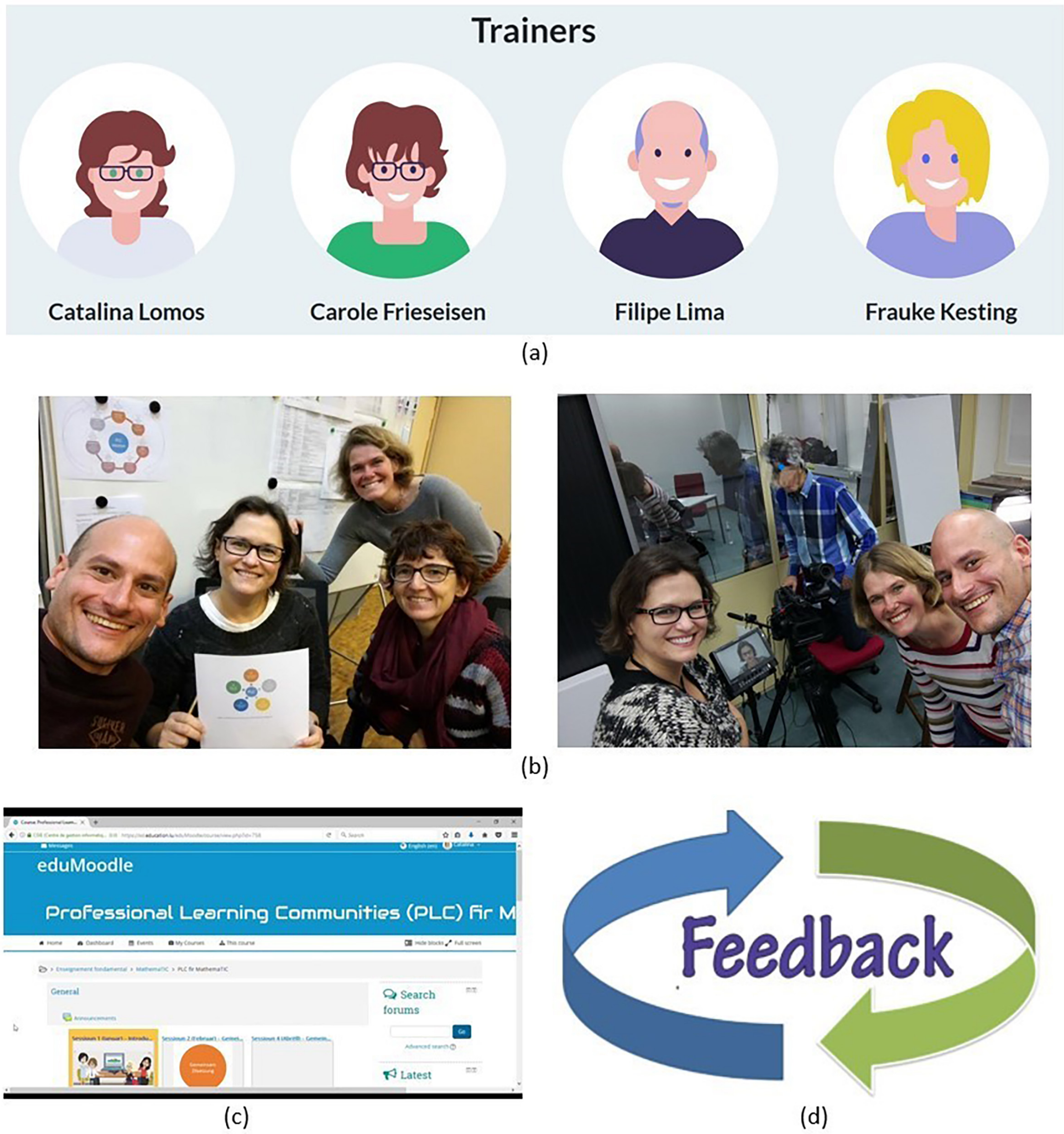

FIGURE 2
(a) The team that developed and delivered the training; **(b)** the process of designing and producing the session materials; **(c)** the Moodle platform; **(d)** the important role of feedback in this PD.

order to ensure the precision of the codes. Level 1 marked if the segment was considered a benefit or a barrier. A Level 2 was indicated whether the segment referred to MathemaTIC or to PLC, considering the dual aim of this training, or to other organizational aspects of the training. Finally, Level 3 indicated the codes of interest for this study, the format and design of the training, its collaborative organization within schools, and its PLC and MathemaTIC (MTIC) content providing an in-depth and specific meaning of the segments in light of the coding scheme (see Supplementary Material for examples).

The first step performed in analyzing the data was to segment the teachers' responses into meaningful segments. Two people, an expert researcher and a trained researcher carried out this task. The second step performed was to code the segments using the provided coding scheme. This time two other researchers coded the segmented data, one expert in the topic and one trained in the topic, with a satisfactory agreement on parts of the coded data.

Results

The perceived barriers

These results are based on the coded segments of the responses provided by the teachers, with a focus only on Level 1 and Level 3 of the coding scheme.

Of the 750 relevant segments for the present coding scheme across the six sessions, 37% of the segments (280) were coded as identifying a barrier of the PD program, as shown in Figure 3.

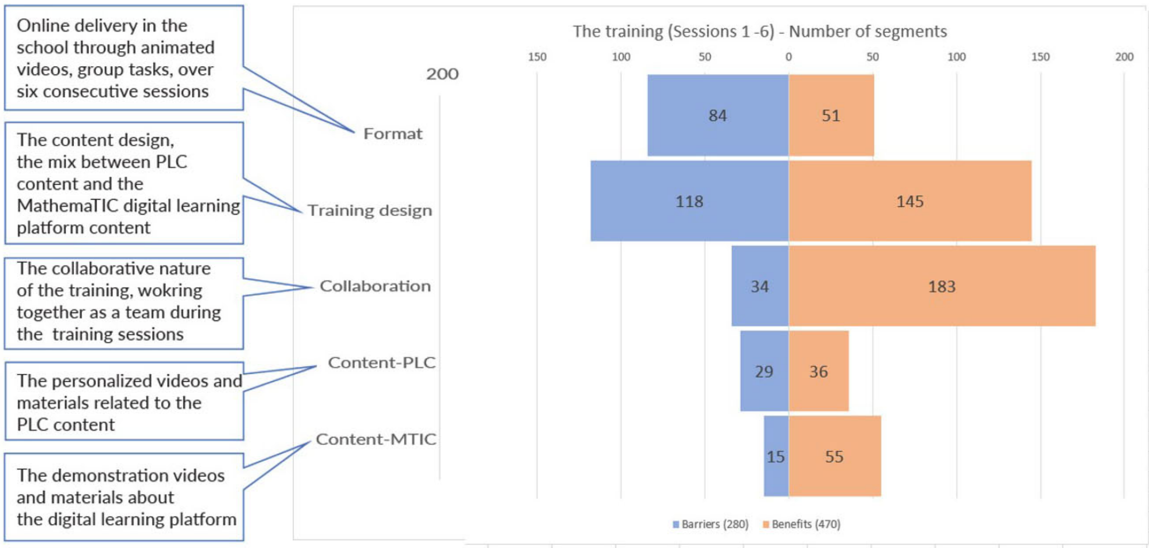

FIGURE 3
Barriers and benefits coded based on teacher reports. *N* = 29 teachers, 6 groups (3 groups of 4 teachers, 2 groups of 5 teachers, 1 group of 7 teachers); sum of segments across sessions 1 through 6.

The figure also includes the definitions of the codes used in Level 3 of the coding scheme. The complete coding scheme can be found in the Supplementary Material.

The Training design, which is a mix of PLC content and MathemaTIC content, and the Format, which is training delivered online but in the school through videos and group tasks, were perceived as barriers. Some examples of the segments coded as barriers to the Training design are "I find the part about MathemaTIC more interesting than the part about PLC"; "we still do not talk enough about the method (MathemaTIC), in my opinion." And some examples of segments coded as barriers of Format are "Unfortunately, we had a lot of problems connecting to and loading the videos"; "The training platform is not very clear, and collaborating on documents is difficult." More such examples of the segments coded across sessions can be found in the Supplementary Material.

The perceived benefits

From the 750 relevant segments for the present coding scheme across all the sessions, 63% of the segments (470) were coded as identifying a benefit of the PD-DT program, as shown in Figure 3.

Collaboration and Training design were perceived as the most beneficial aspects of the training. Some examples of the segments that were coded as benefits of Collaboration are "For me, it was an interesting and new form of collaboration. The exchange between the individual participants was very informative"; "We had lively and motivated discussions." And some examples of segments coded as benefits of the Training design are "I like the mix as it is now: a bit of theory to better understand PLC without having to read a lot of literature, while still keeping the focus on the practice to better understand MathemaTIC and to use it more efficiently in everyday school life." More examples of the segments across sessions can be found in the Supplementary Material.

Going deeper into Collaboration

In terms of Collaboration, we find that it is perceived as the most beneficial across all six sessions. Teachers agree across all sessions that the collaborative format is the most beneficial to their work in this PD program. In addition, Collaboration was perceived as one of the most important benefits, rather than a barrier (see Figure 3). They expressed their positive perception of the PD program as a whole: "We realized how well we function as a group. We have an idea for an interesting future project for our students and our school," and "we were always on the same page, and we agreed to work together on future projects."

It is also important to note whether one group in particular perceived Collaboration as a benefit, or whether all six groups did. As we can see in Figure 4 — Collaboration as benefit, all groups perceived Collaboration as a benefit; one or a few groups did not drive this result. We see that only one group reported that Collaboration is also a barrier for their practice in this PD-DT (see Figure 4 — Collaboration as barrier). This was mainly determined by their difficulty in giving feedback to each other in session 4 (Shared Practice), some of their reports were "Feedback is very difficult in our job because some colleagues would not accept it, even if it is constructive."; or "I feel like we are not in a position to observe others' lessons, this right belongs only to someone superior."

Perceived impact of the PD-DT

In session 5, teachers were asked to rate the perceived impact of the training on their use of DT and MathemaTIC in the classroom. The majority of teachers in all groups indicated that the frequency of their perceived use of MathemaTIC during lessons had increased (14 out of 29 teachers) or greatly increased (9 out of 29 teachers)

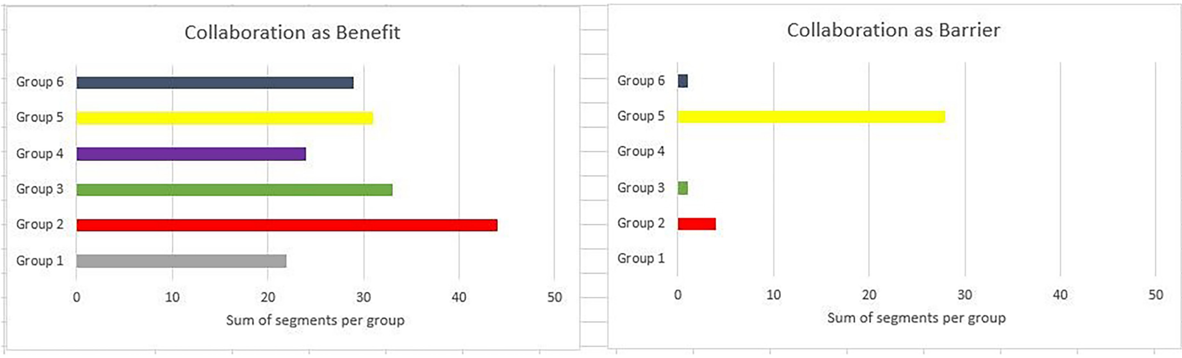

FIGURE 4
N = 29 teachers, 6 groups (3 groups of 4 teachers, 2 groups of 5 teachers, 1 group of 7 teachers); sum of segments across sessions 1 through 6.

since the start of the PD because of the training. However, 6 teachers in 4 groups did not perceive an increase in their use of MathemaTIC. Some teachers wrote "I use MathemaTIC more now than before. The training provides ideas on how to work with the program. This motivates you to try some things."

Discussion and lessons learned

Implications for practice

A first practical implication relates to the Format and the fact that teachers appreciated being able to meet at their school when it was most convenient for them and always have access to the videos and demonstration materials. However, teachers need to be given more time to get used to the digital format, especially in the first session, as they initially reported technical and user-related difficulties with the online PD platform.

In terms of Training design, we have learned that this requires more reflection in the future, and we need to conduct more in-depth analysis of the data in this direction. Teachers do not automatically work well together as a team, and it takes time and support to develop into a highly functioning community (Dingyloudi and Strijbos, 2014; Dingyloudi et al., 2019). For this reason, this PD-DT had a dual goal and focus, with each session first discussing the PC and PLC concept and practice, and second introducing and practicing MathemaTIC. We found in this study that this dual focus – on PLC and on MathemaTIC - was perceived by teachers as both a benefit and a barrier, and it led to dropout after the first session. Further research is needed on how best to support groups of teachers in becoming PLCs while working around a digital tool, and on the types of protocols that scaffold professional learning in various contexts, beyond explicit content and time dedicated during the training.

Collaboration was reported as the greatest benefit of the training by all groups of teachers and in all sessions. Teachers valued this way of working, which was supported by explicit tasks and clear organization in this PD-DT. In our current follow-up work, we are continuing the in-depth analysis of the teachers' reports to understand what exactly supported them in their collaborative work and how we can leverage such generated PLCs for future PD-DTs. We know that teachers trust their knowledgeable colleagues more than almost anything else (Fowler et al., 2022). This may be another reason why collaboration worked and it was perceived as the most beneficial aspect of the training. In addition, teachers mentioned the history of the group in terms of their previous collaboration several times, which also needs to be considered (Dingyloudi and Strijbos, 2014). Shared or deprivatized Practice, through observing each other's teaching and giving feedback was found to be difficult for some groups of teachers, as this is a PLC practice that is generally the least practiced in most countries studied (Lomos, 2017). Nevertheless, learning from shared practice is key in a "praxis" PD program. More reflection and testing of teachers' feedback belief patterns in PD designs (Tam, 2025) is needed to enrich such approaches in the future. This will prevent the lack of shared learning does not become a tension that teachers sometimes report when participating in PLCs (Schaap et al., 2018).

In addition, the content of the training in terms of Content-PLC and Content-MathemaTIC (MTIC) (see Figure 3 for our coding scheme and the Supplementary Material), revealed us that teachers valued the lesson ideas and video demonstrations showing how exactly they could use MathemaTIC in their classrooms. In addition, teachers also appreciated the newer approaches, such as flipped classrooms. In general, as one teacher said, "a bit of theory to better understand PLC without having to read a lot of literature, but the focus is still on the practice to better understand MathemaTIC and to use it more efficiently in everyday school life," best describes what we would recommend for future design of such PD-DT content.

Finally, the length of this PD-DT throughout the school year, facilitated by the five PC characteristics, gave teachers a sense of self-efficacy in using the program and most likely led to best practices and a reported increase in the use of the digital learning platform in their classroom practice. Setting a common goal, identifying barriers to implementation, reflecting together on some effective teaching strategies to overcome the barriers, and testing them through embedded practice sessions allowed teachers to see, discuss, implement, and reflect in a collaborative context. Some of the sessions asked teachers to develop and test out elements in their classrooms and report back on their experiences, while discussing strategies to get the most out of the program, which generated self-reported collaborative action and individual learning. Additionally, analyzing how the program met their specific needs at the end of each session, along with reviewing the results of the collaborative tasks, allowed us to gradually adjust the elements of the program with thoughtful consideration of how they fit with their classroom practice and self-reported needs and expectations.

Lessons learned

Through this study, we have learned to:

1. Ask and listen to teachers' expectations — and adapt to their needs and expectations.
2. Ask teachers for feedback — teachers provided detailed background information and explanations.
3. Provide feedback on teachers' work — teachers appreciated the feedback they received after each session.
4. Team up with teachers — if you are a researcher, design such PD-DTs together with teachers, they will know what their colleagues expect and benefit from.
5. Team up with researchers — if you are a teacher, such collaboration could bring theoretical insights into practice.
6. Materials — create videos and demonstrations of "how-to" examples, and make these materials available to teachers at any time.
7. PLC — Continue to investigate ways to support the development of PLCs in PD, other than explicitly spending time during PD on PLC content and tasks.

Acknowledgments of any constraints

In this study, we only worked with volunteer teachers who enrolled based on their interest generated by the brochure and the promotion we did in schools, and who completed the entire PD program. In addition, teachers clustered within schools dropped out of the study after the first session, thus, these conclusions are based on slightly more than half of the initial group of teachers who enrolled in and completed the training.

Data availability statement

The original contributions presented in this study are included in this article/Supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving humans were approved by the Data Protection Office (DPO) of the Luxembourg Institute of Socio-Economic Research (LISER) who reviewed the project, in line with the internal requirements at the time of data collection. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

CL: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. HS: Conceptualization, Methodology, Writing – review & editing. JWL: Conceptualization, Methodology, Writing – review & editing. FK: Conceptualization, Investigation, Resources, Software, Writing – review & editing. FL: Conceptualization, Investigation, Resources, Software, Writing – review & editing. CF: Conceptualization, Investigation, Resources, Software, Writing – review & editing. ST: Conceptualization, Investigation, Writing – review & editing. SF: Methodology, Writing – review & editing.

Funding

The author(s) declare financial support was received for the research and/or publication of this article. This work was co-funded by SCRIPT (Service de Coordination de la Recherche et de l'Innovation Pédagogique et Technologiques) Luxembourg (Contract "PLC fir MathemaTIC" 2018–2019). SCRIPT co-funded the policy work and implementation.

Acknowledgments

We would like to acknowledge the support of VRETTA in the publication of the PLC for MathemaTIC program website, as well as the research students David Thiry, Thierry Meyer, and Moritz Schaaf, who helped with the translation, coding and reflection of the data. All other partners and contributors to this project are mentioned on the program's website: https://www.mathematic.lu/plc.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The author(s) declared that they were an editorial board member of Frontiers, at the time of submission. This had no impact on the peer review process and the final decision.

Generative AI statement

The author(s) declare that no Generative AI was used in the creation of this manuscript.

Any alternative text (alt text) provided alongside figures in this article has been generated by Frontiers with the support of artificial intelligence and reasonable efforts have been made to ensure accuracy, including review by the authors wherever possible. If you identify any issues, please contact us.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2025.1611730/full#supplementary-material

References

Aldunate, R., and Nussbaum, M. (2013). Teacher adoption of technology. *Comp. Hum. Behav.* 29, 519–524. doi: 10.1016/j.chb.2012.10.017

Bidarian, S., Bidarian, S., and Mohammad Davoudi, A. (2011). A model for application of ICT in the process of teaching and learning. *Proc. Soc. Behav. Sci.* 29, 1032–1041. doi: 10.1016/j.sbspro.2011.11.336

Borko, H., Jacobs, J., and Koellner, K. (2010). "Contemporary approaches to teacher professional development," in *International encyclopedia of education*, 3rd Edn, eds P. Peterson, E. Baker, and B. McGaw (Amsterdam: Elsevier), 548–556. doi: 10.1016/B978-0-08-044894-7.00654-0

Braun, V., and Clarke, V. (2006). Using thematic analysis in psychology. *Q. Res. Psychol.* 3, 77–101. doi: 10.1191/1478088706qp063oa

Bryk, A. S., Camburn, E., and Louis, K. S. (1999). Professional community in Chicago Elementary schools: Facilitator factors and organizational consequences. *Educ. Admin. Q.* 35, 751–781. doi: 10.1177/0013161X99355004

Chaseling, M., Boyd, W. E., Robson, K., and Brown, L. (2014). Whatever it takes! Developing professional learning communities in primary school mathematics education. *Creat. Educ.* 5, 864–876. doi: 10.4236/ce.2014.511100

Dingyloudi, F., and Strijbos, J. W. (2014). Communities of learning practice: Balancing emergence and design in educational settings. *Int. Confer. Learn. Sci.* 13:80802.

Dingyloudi, F., Strijbos, J. W., and de Laat, M. F. (2019). Value creation: What matters most in Communities of Learning Practice in higher education. *Stud. Educ. Eval.* 62, 209–223. doi: 10.1016/j.stueduc.2019.05.006

Donnelly, D., McGarr, O., and O'Reilly, J. (2011). A framework for teachers' integration of ICT into their classroom practice. *Comput. Educ.* 57, 1469–1483. doi: 10.1016/j.compedu.2011.02.014

Fowler, S., Gabriel, F., and Leonard, S. N. (2022). Exploring the effect of teacher ontological and epistemic cognition on engagement with professional development. *Profess. Dev. Educ.* 51, 319–335. doi: 10.1080/19415257.2022.2131600

Hord, S. M. (1997). *Professional learning communities: Communities of continuous inquiry and improvement*. Southwest Educational Development Laboratory.

Hord, S. M., Meehan, M. L., Orletsky, S., and Sattes, B. (1999). *Assessing a school staff as a community of professional learners. Issues about change*, Vol. 7. Austin, TX: Southwest Educational Development Lab.

Kennedy, A. (2016). Professional learning in and for communities: Seeking alternatives discourses. *Profess. Dev. Educ.* 42, 667–670. doi: 10.1080/19415257.2016.1220541

Lee, V. E., and Smith, J. B. (1996). Collective responsibility for learning and its effects on gains in achievement for early secondary school students. *Am. J. Educ.* 104, 103–147. doi: 10.1086/444122

Little, J. W. (1990). The persistence of privacy: Autonomy and initiative in teachers' professional relations. *Teach. Coll. Rec.* 91, 509–536. doi: 10.1177/016146819009100403

Little, J. W., and McLaughlin, M. W. (1993). *Teachers' work: Individuals, colleagues, and contexts*. New York, NY: Teachers College, Columbia University.

Lomos, C. (2012). *Professional community and student achievement*. Enschede: Ipskamp Drukkers B.V.

Lomos, C. (2017). To what extent do teachers in European countries differ in their professional community practices? *Sch. Effect. Sch. Improv.* 28, 276–291. doi: 10.1080/09243453.2017.1279186

Lomos, C., Frieseisen, C., Lima da Cunha, F., and Kesting, F. (2025). "Designing a professional development program for teachers using digital technologies in their classrooms: An application of D.School's "Design Thinking Bootleg" at Stanford University," in *EDULEARN25 Proceedings: 17th International Conference on Education and New Learning Technologies (IATED Academy)*, 9766–9775.

Lomos, C., Luyten, J. W., and Tieck, S. (2023a). Implementing ICT in classroom practice: What else matters besides the ICT infrastructure? *Large Scale Assess. Educ.* 11:1. doi: 10.1186/s40536-022-00144-6

Lomos, C., Luyten, J. W., Kesting, F., and Lima da Cunha, F. (2023b). Explaining variation in teachers' use of ICT: A learning analytics approach. *Interact. Learn. Environ.* 32, 3163–3180. doi: 10.1080/10494820.2023.2170419

Loogma, K., Kruusvall, J., and Umarik, M. (2012). E-learning as innovation: Exploring innovativeness of the VET teachers' community in Estonia. *Comput. Educ.* 58, 808–817. doi: 10.1016/j.compedu.2011.10.005

Louis, K. S., and Kruse, S. (1995). *Professionalism and community: Perspectives on reforming urban schools*. Thousand Oaks, CA: Corwin press.

Louis, K. S., and Marks, H. M. (1998). Does professional community affect the classroom? Teachers' work and student experience in restructuring schools. *Am. J. Educ.* 106, 532–575. doi: 10.1086/444197

Louis, K. S., Marks, H. M., and Kruse, S. (1996). Teachers' professional community in restructuring schools. *Am. Educ. Res. J.* 33, 757–798. doi: 10.2307/1163415

MathemaTIC (2015). *MathemaTIC—Personalized learning in mathematics for every learner*. Available online at: https://www.mathematic.lu/ (accessed March 2025).

McLaughlin, M. W., and Talbert, J. E. (2007). "Building professional learning communities in high schools: Challenges and promising practices," in *Professional learning communities. Divergence, depth and dilemmas*, eds L. Stoll and K. S. Louis (Maidenhead: Open University Press), 151–165.

MENJE (2015). *Digital (4) education—Dossier de presse*. Luxembourg: MENJE.

Mishra, P., and Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teach. Coll. Rec.* 108, 1017–1054. doi: 10.1111/j.1467-9620.2006.00684.x

Newmann, F. M., and Wehlage, G. G. (1995). *Successful school restructuring: A report to the public and educators*. Madison, WI: Center on Organization and Restructuring of Schools.

Ni, L., Bausch, G., and Benjamin, R. (2021). Computer science teacher professional development and professional learning communities: A review of the research literature. *Comput. Sci. Educ.* 33, 29–60. doi: 10.1080/08993408.2021.199366

PLC for/fir Mathematic (2018). *Professional learning communities for MathemaTIC*. Available online at: https://www.mathematic.lu/plc/ (accessed March 2025).

Schaap, H., Louws, M., Meirink, J., Oolbekkink-Marchand, H., Van Der Want, A., Zuiker, I., et al. (2018). Tensions experienced by teachers when participating in a professional learning community. *Profess. Dev. Educ.* 52, 1–18. doi: 10.1080/19415257.2018.1547781

Siskin, L. S. (1994). *Realms of knowledge: Academic departments in secondary schools*. London: The Falmer Press.

Stoll, L., and Louis, K. S. (2007). "Professional learning communities: Elaborating new approaches," in *Professional learning communities: Divergence, depth and dilemmas*, eds L. Stoll and K. S. Louis (Maidenhead: Open University Press), 1–13.

Tam, A. C. F. (2025). Unpacking teacher beliefs on feedback: Shaping multifaceted teacher feedback literacy. *Assess. Eval. High. Educ.* 02, 1–16. doi: 10.1080/02602938.2025.2451086

Wiley, S. D. (2001). Contextual effects on student achievement: School leadership and Professional community. *J. Educ. Change* 2, 1–33. doi: 10.1023/A:1011505709050