An Online and Onsite Training for University Teachers' Professional Development: Methods and Data from the TED-SOEP Project

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Abstract

STEM teaching in higher education is increasingly challenged by uneven student engagement, persistent learning gaps and the difficulty of supporting lecturers in the adoption of student-centred pedagogies. Within this scenario, the Erasmus+ project "Transforming STEM Teacher Education in South Africa through Self-Directed Open Educational Practices" (TED-SOEP) was designed to strengthen the teaching competences of South African university lecturers and professors by promoting the integration of Open Educational Resources (OER) and Open Educational Practices (OEP) within a self-directed learning perspective. This contribution presents the design features and the evaluation outcomes of the professional development pathway implemented by the University of Florence as part of the project. The pathway is structured as an integrated blended training, combining an online environment that supports flexible, self-paced exploration of innovative pedagogical strategies, and a five-day onsite experience that consolidates theoretical principles and contextualises them through collaborative design activities. The 4Ts game, a serious game developed at CNR-ITD, was adopted during the onsite phase to scaffold lecturers' co-design of new teaching scenarios. The training is articulated in five thematic modules dedicated, respectively, to OER and OEP, Inquiry-Based Learning, Problem-Based Learning, Simulations of real-world scenarios and Game-Based Learning. Quantitative and qualitative data collected from 325 online participants and 25 onsite participants from five South African universities show that the integrated design supported differentiated learning trajectories, fostered the appropriation of innovative tools and methods, and enabled high levels of engagement and participants' intention to transfer the practices into their teaching contexts. Beyond presenting evidence on training effectiveness, the paper argues that the integration of self-directed online learning, in-presence consolidation and gamified collaborative design constitutes a methodologically grounded model of professional development for STEM educators.

Keywords: *Open Educational Resources, Open Educational Practices, STEM, Higher Education, Self-Directed Learning, Blended Teacher Training, 4Ts Game.*

1. Introduction

Science, Technology, Engineering and Mathematics (STEM) higher education is currently navigating a phase of profound transformation. Universities worldwide are confronted with the simultaneous demand to widen access, sustain the quality of instruction, and align curricula with rapidly evolving disciplinary and societal needs [1]. In this scenario, lecturers are expected not only to transmit specialised knowledge, but also to design learning experiences that are inclusive, student-centred and capable of mobilising digital tools, real-world data and active learning strategies. Yet, several investigations indicate that the pace of pedagogical innovation among university teaching staff is slower than the rate of change required by these expectations, and that traditional, transmissive teaching still represents a default option in many STEM departments [2].
These tensions are particularly acute in South Africa, where higher education institutions face the dual challenge of redressing structural inequalities inherited from the past and renovating their pedagogical approaches in STEM disciplines. Persistent gaps in student engagement, in scientific literacy, and in the preparation of future teachers represent obstacles for the development of an inclusive scientific workforce. Recent literature has stressed the importance of investing in academic professional development as a lever for systemic change in STEM education and has highlighted the role of Open Educational Resources (OER) and Open Educational Practices (OEP) in promoting more accessible, flexible and collaborative teaching [2].
The Erasmus+ project "Transforming STEM Teacher Education in South Africa through Self-Directed Open Educational Practices" (TED-SOEP, ERASMUS-EDU-2024-CBHE-STRAND-1) responds precisely to these challenges. The project gathers two European universities (University of Florence and Polytechnic Institute of Bragança) and five South African universities (North-West University, University

of the Witwatersrand, University of Pretoria, Sol Plaatje University, and University of South Africa). Its overarching goal is to enhance the teaching competences of South African STEM lecturers, professors and pre- and in-service teachers through training experiences and tools centred on the integration of self-directed OEP and OER.

Within this consortium, the University of Florence designed and implemented a comprehensive professional development pathway, structured as a blended programme consisting of an online course and a five-day onsite training experience. The pathway is intentionally articulated to combine flexibility and depth: the online phase offers each participant the opportunity to engage with a structured corpus of resources at their own pace, while the onsite phase, hosted in Florence in May 2025, consolidates the theoretical groundwork through immersive workshops, expert-led sessions and collaborative design activities. A central feature of the onsite week is the use of the 4Ts game, a serious game developed by the Italian Institute for Educational Technology of the Italian National Research Council (CNR-ITD), conceived to support teachers in the conceptualisation of collaborative learning activities [3]. While the design and outcomes of the online course and of the onsite training have been documented separately in earlier contributions [4], [5], the present paper adopts a more integrative perspective. Its aim is to present the full training package as a unitary intervention, to discuss its rationale in light of the literature on self-directed learning, OER/OEP and teacher professional development, and to bring together quantitative and qualitative evidence emerging from the two phases. By doing so, the paper contributes to the discussion on how blended models can effectively support pedagogical change in STEM higher education, especially when knowledge transfer between different geographical and institutional contexts is at stake.

2. Theoretical Background

2.1 Self-Directed Learning and Open Education in STEM

Self-Directed Learning (SDL) has long been considered a foundational concept in adult education. According to Loeng [6], SDL designates a process in which learners progressively take ownership of their learning by identifying their own needs and goals, selecting strategies and resources to address them, and finally evaluating the outcomes of their efforts. In this perspective, the learner becomes the protagonist of the educational process, while the teacher plays a facilitative role, scaffolding autonomy rather than dispensing prescriptive content. Far from being limited to learners, this paradigm is also relevant for university lecturers themselves, who are increasingly expected to act as autonomous, reflective designers of their own teaching practice.

OER have emerged in recent decades as a powerful infrastructure to support such SDL processes. Defined as freely accessible learning materials that can be reused, adapted and shared, OER include textbooks, multimedia content, datasets, simulations and assessment instruments. Hilton [7], in a synthesis of empirical studies, reported that OER are associated with student outcomes that are equal to, or in some cases better than, those obtained with traditional commercial materials, while at the same time reducing economic barriers to access. The complementary notion of OEP broadens this perspective: it shifts the focus from artifacts to the pedagogical practices through which open resources are designed, integrated and re-elaborated within authentic teaching contexts.

In STEM higher education, OER and OEP are particularly promising. They allow lecturers to integrate up-to-date scientific content, interactive simulations, and inquiry-oriented activities, while preserving the flexibility needed to adapt materials to local contexts. Kleinschmit and colleagues [2] have documented how the development and dissemination of OER through linked communities of practice can act as a sustainable engine for STEM teaching reform, fostering both faculty professional growth and student engagement. At the same time, the long-term sustainability of OER initiatives remains a research topic in its own right: as Tlili et al. [8] point out, the integration of OER into the everyday fabric of teaching, research and community engagement is what ultimately makes openness viable beyond pilot projects.

2.2 Blended Models for Teacher Professional Development

A growing body of evidence suggests that blended models, combining online and in-presence components, are particularly effective for teacher professional development [9]. Synthesising qualitative research on the topic, scholars have identified key components of effective blended programmes, including the alignment between online and onsite activities, the explicit support for collaboration among participants, the modelling of innovative teaching strategies and the provision of opportunities for transfer to participants' own classrooms [10].

Within blended programmes, the online component is particularly suited to address the diversity of the audience: participants typically vary in disciplinary background, prior experience with educational technologies and degree of familiarity with student-centred approaches. A modular, asynchronous environment can accommodate this heterogeneity by allowing each user to progress according to their starting point and goals. The onsite phase, in turn, offers an irreplaceable opportunity for situated learning, social interaction, and joint design with peers and experts, thereby compensating for the more individualistic nature of online study.

2.3 Collaborative Design and the 4Ts Game

A specific challenge in teacher professional development is to translate theoretical knowledge into concrete pedagogical decisions. To address this gap, several research groups have proposed structured tools and serious games that scaffold learning design processes. Among these, the 4Ts model and the related 4Ts game, developed at CNR-ITD, have been widely studied as instruments to support teachers in the conceptualisation of collaborative learning activities [3], [12]. The model identifies four interrelated dimensions: the Task that learners will undertake; the Time over which the activity unfolds; the Team configurations that organise students' work; and the Technology that mediates and supports the interaction. By making these dimensions explicit and inviting designers to negotiate them with their peers, the 4Ts framework operationalises learning design as a deliberate, evidence-informed activity.

3. Methodology

This section describes the design and the implementation of the training package. It first illustrates the underlying instructional architecture, before detailing the online and the onsite components, the role of the 4Ts game, the participants involved, and the evaluation procedures adopted in each phase.

3.1 Architecture of the Training Package

The TED-SOEP training package designed by the University of Florence is organised around five thematic modules, each focused on a teaching strategy considered particularly relevant for STEM higher education: (1) OER and OEP, (2) Inquiry-Based Learning (IBL), (3) Problem-Based Learning (PBL), (4) Simulation of real-world scenarios, and (5) Game-Based Learning (GBL). The same five modules are addressed both in the online course and in the onsite training, but with complementary emphases and methodologies. The online phase prioritises individual exploration, theoretical grounding and gradual application; the onsite phase prioritises consolidation, contextualisation in participants' disciplines and collaborative design.
This articulation reflects an intentional pedagogical choice. Rather than juxtaposing two separate experiences, the package is conceived as a continuum: the online environment activates prior knowledge and introduces the conceptual building blocks of each strategy, while the onsite week deepens these foundations through expert-led sessions, demonstrations from STEM disciplines, and structured design tasks. Together, the two phases enact the cycle of activation, demonstration, application, and integration that lies at the heart of Merrill's principles [11].

3.2 The Online Course

The online course is hosted on the project platform (https://www.tedsoep.org/TR_online.php) and is freely accessible to South African STEM lecturers, professors and pre- and in-service teachers. Each of the five modules follows a common four-phase structure inspired by Merrill's First Principles of Instruction: an Activation phase, which introduces the topic and stimulates motivation; a Documentation phase, which presents two video lessons supplemented by automatic subtitles, and written transcripts in order to accommodate different learning preferences; an Application phase, which suggests interactive platforms and digital tools that can be used by lecturers and their students to design or carry out activities; and an Integration phase, which synthesizes the key contents and offers self-evaluation checklists. Each module is composed of a five-item multiple-choice test, administered before and after the learning activities, allowing participants to monitor their own progress and provides the research team with quantitative indicators of skills acquisition.
The five tests are aligned with the specific learning objectives of each module. For instance, in Module 1 participants are asked to recognise the criteria that allow the quality of OER to be evaluated; in Module

2 they reflect on the goals of the conceptualisation phase of inquiry-based activities; in Module 3 they identify the role of the teacher within problem-based scenarios; in Module 4 they discuss the skills that simulations can foster in STEM; in Module 5 they consider the alignment between game-based learning and the goals of higher education. Through the entire course, the design embraces a self-directed perspective: learners can navigate modules in different orders, revisit content asynchronously, and integrate the suggested applications into their own professional reality.

3.3 The Onsite Training

The onsite training, titled “Innovative STEM Teaching in Higher Education: from Theory to Action”, was held in Florence from 26 to 30 May 2025. It was organised over five working days, with each day dedicated to one of the five thematic modules, and articulated into a morning and an afternoon session. The mornings hosted expert-led lectures, demonstrations and example analysis delivered by professors, researchers and research fellows of the University of Florence active in different STEM areas. The presentations illustrated concrete applications of each strategy in real disciplinary contexts: for example, the integration of artificial intelligence in the design of OER; the use of LEGO-based hands-on tasks to support inquiry-based learning in engineering; the simulation of complex systems through NetLogo for game-based learning; the deployment of 360-degree video in agricultural studies; and the implementation of problem-based scenarios with the support of digital technologies.
The afternoons were dedicated to collaborative workshops in which participants, organised in small groups, were invited to design new STEM teaching activities through the 4Ts game framework [3]. Each group worked iteratively on the four dimensions of Task, Time, Team, and Technology, transforming the theoretical inputs of the morning into concrete teaching scenarios that could be deployed in their home institutions. The game served as both a scaffold for design decisions and as a shared language across participants of different STEM disciplines, supporting the negotiation of pedagogical choices and the exchange of expertise.

3.4 Participants

A total of 325 South African professors, lecturers, pre-service and in-service STEM teachers completed the online course. According to their pre-test scores in each module, they were grouped into three profiles to allow a more nuanced analysis of the impact of the training: Low-skills users (0–2 correct answers, with limited or no prior knowledge), Medium-skills users (3–4 correct answers, with moderate prior knowledge or experience), and High-skills users (5 correct answers, with consolidated prior knowledge). This profiling acknowledges the heterogeneity of the audience and supports the interpretation of pre/post variations in light of different starting points.
The onsite training in Florence involved 25 university lecturers from the five South African partner universities, with five participants per institution. Their academic profiles ranged from Lecturers (14) and Senior Lecturers (7) to Associate Professors (3) and Full Professors (1); two of them held additional roles as Directors or Deputy Directors of their Department. The disciplinary backgrounds were equally distributed across Mathematics education (28%), Science education – including natural science, life science and chemistry education (28%), Technology education (28%), with the remaining 16% spread across Computer education, Physics, early science and Mathematics education, and teacher education. This composition deliberately mirrors the variety of fields that compose STEM in higher education and feeds the project's ambition to disseminate good practices broadly.

3.5 Evaluation Procedures

The two phases of the training were monitored through complementary evaluation strategies. The online course used pre/post multiple-choice tests at module level: each test consisted of five closed-ended items aligned with the module's learning objectives. The variation between pre- and post-test scores was interpreted differently depending on the user profile: as a learning gain for Low- and Medium-skills users, and as a consolidation of prior knowledge for High-skills users.
At the end of the onsite training, participants completed a satisfaction questionnaire articulated in five dimensions, each rated on a 1–10 scale: (i) relevance of the training contents, (ii) effectiveness of the teaching methodology, (iii) accessibility of the didactical resources, (iv) clarity of the training contents, and (v) competence of the trainers. The questionnaire also included open-ended fields, where participants could elaborate on what they considered most valuable, what could be improved and how they intended to use the experience in their own work.

4. Results

4.1 Outcomes of the Online Course

The analysis of pre- and post-test scores in the online course highlights a positive impact on participants' competences, with patterns that vary across the three user profiles. Low-skills users show consistent improvements across all five modules: their average pre-test scores, ranging from 1.3 to 1.7 correct answers, rise to post-test averages between 3.5 and 4.3. The largest gain is observed in Module 1, dedicated to OER, where the mean increases from 1.5 to 4.0, and in Module 5, on Game-Based Learning, where the mean rises from 1.6 to 4.3. Medium-skills users show more contained but still discernible improvements, generally moving from average scores around 3.5–3.7 to post-test means between 4.0 and 4.4; the only exception is Module 4 on simulations, where the variation is marginal (from 3.6 to 3.7). High-skills users, who already obtained the maximum score in the pre-test, tend to confirm their performance in the post-test, signalling a consolidation rather than a learning gain.
These trends are reinforced when the focus shifts from group to the proportion of users who improved (or maintained the maximum) between pre- and post-test, as summarised in Table 1. The percentage of Low-skills users who increased their correct answers exceeded 80% in four modules out of five, peaking at 93% in the OER module. Among Medium-skills users, the proportion of participants who improved their scores ranges from 51% (Module 4, Simulations) to 72% (Module 3, PBL). High-skills users maintain the maximum score in 79% to 86% of cases, depending on the module. Taken together, these results indicate that the online course supported differentiated learning trajectories: bridging gaps for less experienced users, refining knowledge for intermediate ones, and consolidating expertise for advanced participants.

Table 1. Percentage of online course participants who improved or consolidated their performance, by user profile and module.

Profile / Indicator	Mod 1 OER	Mod 2 IBL	Mod 3 PBL	Mod 4 SIM	Mod 5 GBL
Low-skills users (% improving)	93%	84%	75%	85%	92%
Medium-skills users (% improving)	64%	64%	72%	51%	62%
High-skills users (% maintaining max score)	84%	83%	84%	86%	79%

The marked variation between Module 4 (Simulations) and the other modules among Medium-skills users deserves particular attention. The smaller gain may be related to the intrinsic complexity of simulation-based teaching, which requires the integration of disciplinary content, technological tools and reflection on cognitive processes. It also resonates with feedback collected during the onsite phase, which suggested that the simulation module would benefit from additional space for case-based discussion and from more practical examples drawn from participants' own disciplines.

4.2 Outcomes of the Onsite Training

Engagement during the five-day onsite training was high. Participants attended morning and afternoon sessions consistently and contributed actively to discussions and design tasks. The satisfaction questionnaire confirmed a very positive perception of the experience. The dimension that received the highest score was “competence of the trainers”, with an average of 9.2/10, signaling appreciation for the involvement of professors and researchers from different STEM areas. Relevance and clarity of contents were rated 8.6 and 8.5 respectively, while effectiveness of the teaching methodology and accessibility of the resources received 8.2 and 8.1. The overall mean score across the five dimensions was 8.5/10. Table 2 summarizes these results.

Table 2. Average scores attributed by onsite participants to each dimension of evaluation.

Dimension of evaluation	Mean score (1–10)
Relevance of the training contents	8.6
Effectiveness of the teaching methodology	8.2
Accessibility of the didactical resources	8.1
Clarity of the training contents	8.5
Competence of the trainers	9.2
Overall average	**8.5**

Beyond the quantitative ratings, the qualitative answers provided by participants offer a richer picture of the perceived value of the experience. Three thematic clusters emerged consistently. The first cluster concerns the discovery of new digital tools, with particular emphasis on artificial intelligence applications, simulation environments and AI-supported creation of OER. Approximately eleven respondents out of twenty-five made explicit reference to this dimension, mentioning the intention to integrate the new tools into their teaching practice as soon as they returned home. The second cluster concerns the appropriation of innovative teaching strategies. Several participants stressed the value of being exposed to different active-learning approaches and indicated that they would translate them into modules for pre-service teacher education at their universities. The third cluster concerns the perceived expertise of the trainers and the multidisciplinary nature of the offer, which several respondents associated with the variety of perspectives proposed across the five days.
An additional aspect worth highlighting is the dual orientation towards teaching and research, that participants attributed to the experience. A subset of respondents reported that the training was inspirational not only for their classroom practice, but also for their research agenda, suggesting potential collaborations with European partners and stimulating new lines of inquiry. The collaborative climate of the workshops, supported by the 4Ts game and by the constant interaction between trainers and trainees, was likewise mentioned as a factor that strengthened the learning experience and that fostered a sense of community among participants from different institutions.
Critical observations were limited but informative. A few respondents noted that the overall duration of the training was demanding, given the density of contents addressed every day. Others suggested that more space could be allocated for participants to share their own experiences and to discuss how each strategy could be adapted to their local contexts. Some participants asked for additional practical examples in specific modules, in line with the more limited gains observed in the simulation module of the online course.

5. Discussion

The integrated reading of the online and onsite phases offers several insights for the design of professional development programmes for STEM higher education. A first point concerns the complementarity of the two components. The online course supported a flexible, self-paced exploration of the five strategies and demonstrated the ability to address users with very different starting points, providing measurable gains. The onsite training, in turn, situated these contents within concrete disciplinary practices, gave space to peer interaction and modelled how innovative strategies are negotiated, refined and adapted to specific teaching contexts.
A second point concerns the role of the 4Ts game. The game enabled participants to translate the morning lectures into structured design exercises, providing shared vocabulary across very different disciplinary backgrounds and supporting the kind of conceptualisation work that is at the core of effective learning design [3], [12]. From a methodological standpoint, the systematic use of the 4Ts framework across the five thematic days produced a recognisable pattern of activity – input, design, refinement, sharing – that contributed to the perceived coherence of the week. The high score attributed to the competence of trainers and to the clarity of contents is consistent with this interpretation: the game offered a robust scaffold within which trainers' expertise could be effectively channelled into design-oriented tasks.
A third point concerns the alignment of the package with the principles of self-directed learning. By offering modular online materials, embedded self-evaluation, and the possibility for participants to revisit content according to their needs, the online course is consistent with the SDL perspective described by

Loeng [6]. The onsite phase complements this by promoting self-directed micro-decisions within the design tasks: participants negotiate task complexity, technology choices and team configurations as a function of the contexts they will eventually return to. In this sense, the package not only teaches innovative pedagogical strategies, but also models a self-directed approach to professional development, in line with Kleinschmit and colleagues' [2] argument about communities of practice as drivers of sustainable change in STEM education.
A fourth point relates to the broader transferability of the model. TED-SOEP is built around the explicit ambition of facilitating the circulation of expertise between European and South African universities. The trained lecturers and professors, in turn, were expected to act as multipliers within their own institutions through national workshops, reaching additional colleagues, and progressively diffusing the practices acquired in Florence. The intention to apply the methods, repeatedly expressed in the qualitative answers, suggests that this multiplier function is plausible. At the same time, the suggestions for additional spaces of experience-sharing and for further practical examples reinforce the importance of explicitly designing for adaptation: when programmes are intended to circulate across very different cultural and institutional contexts, opportunities for participants to recontextualise contents are not optional features, but constitutive components of the design.
Some limitations need to be acknowledged. The evaluation strategies adopted in the two phases are different in nature: the online course relied on multiple-choice tests aligned with module learning objectives, while the onsite training was assessed through a satisfaction questionnaire and qualitative comments. While the two perspectives are complementary, they do not allow a direct comparison of skills acquisition between phases. In addition, the empirical evidence collected so far focuses on participants' immediate reactions and on short-term changes in declarative knowledge; medium- and long-term effects, including the actual implementation of the strategies in participants' classrooms, will need to be investigated in subsequent project activities. Finally, the analysis of qualitative data was based on a relatively small number of respondents and identified recurring themes rather than statistically robust patterns; further data collection during the national workshops will help to refine these findings.
It is also worth noting that the integration of the 4Ts game with the five thematic modules helped to mitigate a recurrent risk in teacher education programmes, namely the gap between exposure to innovative content and its actual translation into classroom practice. By systematically requiring participants to design new activities at the end of each daily session, the workshops produced concrete artifacts that could be discussed, refined and shared among groups. This rhythm – input, design, refinement, sharing – contributed to a culture of evidence-informed pedagogical decision-making which is consistent with the broader objectives of the TED-SOEP project and with the literature on linked communities of practice in STEM education [2].

6. Conclusions

This paper presented the integrated training package designed by the University of Florence within the TED-SOEP project, with the goal of strengthening STEM teaching competences among South African higher education lecturers and professors. The package combines an online course, organised in five modules and grounded in Merrill's First Principles of Instruction, with a five-day onsite training in Florence that consolidates contents through expert-led sessions and gamified design workshops based on the 4Ts framework. The two phases share the same conceptual scaffolding – the five themes of OER and OEP, Inquiry-Based Learning, Problem-Based Learning, Simulations and Game-Based Learning – but mobilise different methodological resources to address them.
Quantitative and qualitative evidence indicates that the package supported differentiated learning pathways. The online course produced measurable gains for less experienced users, more contained but visible improvements for intermediate users and consolidation effects for advanced participants. The onsite training was rated very positively across all dimensions of evaluation, with particular appreciation for the competence of the trainers, the relevance and clarity of the contents, and the opportunity to engage with innovative tools and methods within a collaborative environment. Participants explicitly indicated their intention to transfer the acquired strategies to their own classrooms and, in some cases, to their research practice.
Beyond its specific outcomes, the experience suggests that integrated blended designs that combine online SDL, in-presence consolidation and gamified collaborative design can constitute a viable model of professional development for STEM educators. Future iterations of the package will benefit from the suggestions emerged during the evaluation: more space for sharing participants' experiences, additional practical examples in selected modules, and refined strategies for follow-up beyond the training week.

As the project moves forward, the lessons learnt within TED-SOEP can inform similar initiatives where pedagogical innovation needs to travel between higher education institutions, disciplines and geographical contexts, while preserving the autonomy and the contextual sensitivity of the lecturers it aims to support.

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