Practices and Strategies for Teacher Professional Development in Education 4.0

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Abstract	In the era of Education 4.0, characterized by digital learning and rapid changes in labor market requirements, the professional development of teachers becomes a strategic priority for education systems. This theoretical article explores the practices and strategies of teacher professional development in relation to the new requirements of Education 4.0, with a focus on continuous training, adaptability, collaboration and pedagogical innovation. Fundamental concepts such as educational coaching, pedagogical mentoring and professional learning communities are analyzed, in correlation with validated international models and relevant local implementations. The paper includes examples of good practices from Romania, such as the SMART-Edu Strategy, iTeach, EDIS-PED, Aspire Teachers, emphasizing their contribution to the continuous and sustainable training of teachers, supporting the priorities of the European Union. The conclusions highlight the need for a coherent and systemic approach to lifelong learning, considered essential for supporting a genuine transformation of education in the context of the fourth industrial revolution.
Keywords: coaching, digitalization, Education 4.0, mentoring, professional learning communities, teachers' professional development	

1. Introduction

Changing times influence all areas of society, including education. The Industrial Revolution 4.0 is bringing major transformations in the economy, industry, government, politics and education through advanced technologies such as artificial intelligence, nanotechnology, genetic engineering, supercomputing and automation (Risdianto, 2019). This revolution emphasizes the development of virtual technologies that reduce the need for human labor, profoundly influencing all aspects of everyday life (Đuricin & Herceg, 2018). In this context, the educational system must train competitive human resources capable of meeting new challenges. Achieving these goals requires effective educational leadership and well-trained teachers. According to Sasongko & Sahono (2016), innovation is a creative activity that generates valuable ideas, concepts, objects, or solutions for society. In education, this type of innovation is essential for adapting continuously to technological and social change.

Education 4.0 marks a stage in which educational institutions adopt modern teaching methods, advanced digital tools, and smart, sustainable infrastructures. Miranda et al. (2021) identified four key dimensions of the model: educational infrastructure, learning methods, key competencies, and information and communication technologies. Together, these dimensions provide a strategic framework for reforming education to meet the demands of the 21st century. Teachers must possess the same key competencies required of students: critical thinking, digital skills, and problem-solving ability. These competencies are essential in the modern labor market (Peredrienko, 2020). The quality and professionalism of teachers directly correlate with the effectiveness of the educational process, especially in the context of the digital revolution.

Man et al. (2017) emphasize that the transformation of education is impossible without well-prepared teachers. Furthermore, poor student outcomes are often associated with a lack of teaching competence among teachers (Adzhar & Radzi, 2020). The OECD (2019a) also indicate the importance of continuous professional development. They state that to meet the increasingly complex demands of modern schools, teachers need to constantly update their knowledge and skills in response to the needs of their students. Therefore, for the education system to effectively respond to new global challenges, it is essential that teachers be innovative, flexible, and committed to continuous learning, thus becoming active agents of educational change.

2. Theoretical foundation

2.1. Teachers' professional development

Professional development is considered essential to ensuring the quality of education and a teacher's ability to adapt to the demands of contemporary society. According to researchers Ivanova and Antonov (2019), this process involves actively transforming one's professional identity by strengthening specialized skills and developing personal traits, motivation, communication, and self-reflection skills. These skills contribute to teachers' self-actualization in creative and effective ways.

Similarly, Desimone et al. (2006) emphasize that professional development is fundamental to improving specialist knowledge and enhancing teaching quality. Nowadays, in-service training has become a systemic necessity, essential for maintaining teachers' professional relevance, not just a recommendation.

The strategic importance of the teaching profession is also recognized in legislation. In Indonesia, for example, the teaching profession has been formally regulated since 2005. Regulation No. 55/2017 (Permenristekdikti) of the Ministry of Research, Technology and Higher Education establishes standards for teacher training and defines teachers as professional educators responsible for instructing, assessing, and supporting students in all educational cycles.

A major component of professional development is integrating digital technologies into education; however, this transition presents challenges. One such challenge is the lack of consensus on the concept of the digitization of education. Uvarov et al. (2019), for example, define digitization as achieving educational outcomes by personalizing learning with digital technologies. Vaindorf-Sysoeva & Subocheva (2020), on the other hand, describe digitization as the transfer of pedagogical functions into a digital space through the use of big data to organize learning, promote student autonomy in processing information, and use mobile technologies to expand access to knowledge and collaboration.

Dautova et al. (2020) define digitization as translating the educational process into a unified digital ecosystem based on hardware and software infrastructure. This transformation aims to qualitatively change the interaction between educational participants and optimize learning outcomes. This transformation entails reassessing the role of vocational training. According to Bagautdinova

(2002), one essential aspect of computerizing education is using ICT as an integral part of teaching methodology and educational management, not just as technological support. This requires the continuous and systematic development of teachers to leverage the technological potential for pedagogical purposes and adapt to the demands of a computerized society.

2.2. Forms of teachers' professional development

Professional development is an ongoing process essential to the sustainability and effectiveness of a teaching career (Chin et al., 2022). The literature highlights multiple forms of professional development: formal, non-formal, and informal. They are defined by their own characteristics, advantages, and limitations; together, they contribute to the development of adapted, innovative pedagogical practices.

According to TALIS (OECD, 2019b), professional development falls into two categories: formal and informal. Formal professional development includes participation in courses, workshops, educational conferences, seminars, qualification programs, observation visits to other schools, involvement in teacher networks, and individual or collaborative research. It also includes mentoring, peer observation, and coaching activities. Informal professional development consists of less structured activities, such as literature reviews and informal peer dialogues on pedagogical strategies and practices. Formal professional development usually occurs in an organized setting, such as an online course or workshop (Lockee, 2021; Pires, 2021). These settings provide access to the latest methodological innovations. In contrast, informal learning often occurs spontaneously in various contexts, such as professional network interactions or exchanges of best practices with other educators.

Recent studies confirm that formal and informal learning complement each other and should be approached in an integrated way. For instance, during the pandemic, teachers benefited from both formal training offered by ministries of education and informal discussions through social networks to rapidly acquire the necessary skills for distance teaching (Trust et al., 2020).

In this context, Abaci et al. (2021) and Chin et al. (2022) emphasize that teachers relied on their own competencies and institutional support to overcome digital challenges. This confirms the idea that professional development is an ongoing learning process supported by educational infrastructure and

personal initiative. Similarly, Korthagen (2016) emphasizes an important point: the effectiveness of professional development hinges on its relevance to classroom practice. He emphasizes the significant gap between theory and practice and categorizes professional development into several levels:

1. Simple explanation of theories to teachers;

    1.1. Explanation of theory accompanied by concrete example;

2. Integration of new methods into the active curriculum;

3. Emphasis on reflective learning, centered on teachers' real-life experiences, in order to strengthen professional identity.

This approach emphasizes teachers' personal development and is supported by Avidov-Ungar & Herscu (2019), who state that effective programs change teaching behavior and positively influence student learning.

Furthermore, research shows that professional development success depends not only on program content but also on teachers' personal and professional characteristics, such as teaching experience, openness to change, professional awareness level, and learning process expectations (Lockee, 2021; Sancar et al., 2021; Wuryaningsih et al., 2021).

2.3. Teacher 4.0 profile

The transformations brought about by Industry 4.0 have profoundly influenced the way we think, act, and communicate, including in education. In an ever-changing world, rapid adaptability, openness to new ideas, risk-taking, and creativity have become essential qualities for those in education (Noh & Karim, 2021). Although this technological revolution poses risks and uncertainties for schools and teachers, it also presents valuable opportunities, such as openness to innovative teaching methods and creative inquiry, which can enhance teacher effectiveness and student achievement (Uspayanti, 2021).

In this context, the concept of "Teacher 4.0" emerges as a new professional model that lies at the intersection of technology, pedagogy, and humanity. Teacher 4.0 is closely related to Education 4.0, an emerging educational paradigm based on the accelerated evolution of digital technologies and learner-centered practices (Peredrienko et al., 2020). A 4.0 teacher is characterized by flexibility, professional autonomy, an openness to lifelong learning, and interdisciplinary skills. They are teachers who can integrate modern technological tools into their teaching, create diverse educational contexts, and facilitate learning (Abdelrazeq, 2016; Smolyaninova & Bezyzvestnykh, 2019).

According to Abdelrazeq (2016), Teacher 4.0's responsibilities are marked by three major categories of challenges: human and didactic (e.g., adapting one's pedagogical style), organizational (e.g., integrating into flexible school structures), and technological (e.g., using smart equipment and digital platforms). In the face of these changes, teachers must manage the demands of a digitized environment and interact with a new generation of "digital native" learners (Afrianto, 2018).

Three innovative educational scenarios have been proposed to meet the new challenges (Abdelrazeq, 2016):

a) Monitoring student attention: using smart devices that detect movements and physiological reactions to increase engagement and provide teachers with automated feedback.

b) Real-time self-feedback: using wearable technologies (e.g., wireless headphones or AR glasses) to provide teachers with suggestions on their teaching behavior to facilitate immediate improvement;

c) Multilingual communication: integrating digital solutions that support learning in linguistically diverse classrooms and ensure equitable access to content and a shared educational experience.

For a sustainable transformation of education, it is important that these changes be translated into practice. Thus, three competence domains specific to Education 4.0 have been defined (Koenen et al., 2015):

1. Pedagogy in Education 4.0: This area involves designing a competency-based, learner-centered learning process that includes authentic tasks, critical reflection, autonomous learning, and alternative assessment methods. This approach promotes a socio-constructivist view of learning (Vygotsky, 1978; Lave & Wenger, 1991) in which teachers become facilitators who actively collaborate with other educational stakeholders.

2. Digital Technologies in Education 4.0: This dimension addresses teachers' ability to integrate technology into teaching to transform and enrich students' experience. Key competencies include supporting self-regulated learning, promoting peer collaboration, and designing hybrid and online courses

using tools such as learning management systems (LMS) platforms.

3. Learning Ecosystem in Education 4.0: The focus is on collaboration between teachers, students, and external partners, such as employers and the community.

Emotional intelligence, self-regulation, and social skills are essential here (Goleman, 2001; Mayer & Salovey, 1997). These skills enable the development of authentic learning communities based on empathy, dialogue, and shared solutions. The elements of knowledge, attitude and action that define the competences of the Teacher 4.0 must be approached in an integrated and complex way, to ensure balanced professional development (Barnett, 2009). Theoretical knowledge or practical experience are not enough; an open mindset, a commitment to lifelong learning and an adaptable professional vision are also necessary (Eraut, 1994).

A teacher's attitude toward change and willingness to evolve are fundamental to the success of Education 4.0.

3. Effective professional development practices and strategies

3.1. Mentoring and coaching

In recent years, instructional coaching and mentoring have become essential components of in-service teacher education. They are recognized for increasing pedagogical effectiveness and supporting early careers in education. According to Weston & Clay (2018), coaching is a process that facilitates learning and personal development through reflective dialogue, goal formulation, and active guidance. The coach does not offer solutions, but rather helps the individual discover them, regardless of their level of expertise.

In contrast, Jones (2018) defines mentoring as an asymmetrical relationship in which an expert provides professional knowledge and serves as a role model for a novice, offering specific support for their professional integration and development. This process involves modeling, observation, and direct exemplification. Recent research points to three theoretical frameworks commonly used in coaching program design:

a) The Zone of Proximal Development (ZPD; Breive, 2020), which emphasizes the importance of support tailored to the teacher's developmental level.

b) The Presage-Process-Product Model (Biggs, cited in Ganotice & Chan, 2019), which highlights the influence of context, process, and outcomes in training.

c) The GROW Model (Eriksen et al., 2020; Hastings & Pennington, 2019), which provides a four-step structure: goal, reality, options, and will.

These models all help maximize professional potential and are tailored to the mentee's profile (Lord et al., 2008).

In China, mentoring is an integral part of beginning teachers' professional career paths. Teachers are paired with mentors based on personal and professional compatibility. The mentoring process involves institutional induction, lesson observation, structured feedback, and shared goal setting (Wang et al., 2004). In the Philippines, Congcong & Caingcoy (2020) identified the systematic use of post-observation feedback by school leaders as a coaching method. School leaders use the results of classroom observations to support in-service teacher training and enhance the quality of education through professional reflection.

Research suggests these forms of support can significantly impact professional autonomy, motivation, and performance. For instance, Veenman et al. (1998) demonstrated in a study conducted in the Netherlands that a coaching and mentoring program for novice teachers significantly increased levels of pedagogical self-analysis and improved instructional effectiveness.

Additionally, Devine et al. (2013) and Gormley & van Nieuwerburgh (2014) emphasize that these practices facilitate active learning through dialogue and reflection. Additionally, Kets de Vries (2005) argues that group coaching is effective in creating effective teaching teams.

Educational leadership plays a critical role in implementing these practices. Congcong & Caingcoy (2020) note that school principals are mentor-coaches who provide feedback after observing lessons. Using these tools repeatedly optimizes learning and contributes to continuous improvement in teaching and academic performance. All studies agree on one essential idea: regardless of the model applied (ZPD, GROW, cognitive coaching, etc.), coaching and mentoring ultimately aim to sustainably develop teachers' professional skills and improve educational quality (Memorial, 2024; Jones, 2018).

3.2. *Professional learning communities (PLC)*

Initial training is not enough to meet today's challenges, and teachers can only become experts if they are involved in continuous professional development throughout their careers (Van der Klink et al., 2016). In this regard, professional learning must be reflective, sustainable, and relevant to practice rather than casual or purely theoretical (McGee & Lawrence, 2009). A central model for collaborative development is the Professional Learning Community (PLC), which DuFour & Eaker (1998) conceptualized as the educational equivalent of organizational learning (Senge, 1990). The precise definition of PLCs remains complex and adaptable depending on the context (Chen et al., 2016; Lomos et al., 2011), but researchers emphasize that they must integrate three dimensions: professional, learning, and community (Hairon et al., 2015). Thus, each school can develop its own operating formula (Bolam et al., 2005).

Lesson observation, a frequent practice in PLCs, contributes significantly to continuous improvement. Novice teachers learn effective teaching methods, while experienced teachers refine theirs (Wang & An, 2023). According to Hord & Tobia (2012), collaborative learning and the sharing of pedagogical practices are fundamental to the PLC model. Recently, educational research and policy have increasingly focused on developing Professional Learning Networks (PLNs) - groups of teachers from different schools who collaborate to improve teaching and learning (Poortman & Brown, 2017). These networks can take the form of research-action partnerships or lesson analysis groups. Stoll (2010) and Chapman (2014) argue that the complexity of today's world demands collaboration between schools because educational challenges can no longer be solved at the individual unit level. In the Netherlands, professional development is still dominated by traditional formats, such as courses and symposia, which are predominantly conducted outside of school (OECD, 2019a). However, interest in collaborative learning in the form of professional learning communities (PLCs) or internal pedagogical support networks is growing in educational policy and school practice (Admiraal et al., 2019).

Internationally studies such as those by Tynjälä (2013) demonstrate that learning naturally occurs in professional social communities through real-life problem-solving, material development, and practical reflection. Robbers and Vermeulen (2018) argue that scholarly literature increasingly reflects this interest, with a growing number of publications on professional collaboration in schools. An emerging dimension of professional development is online communities of practice. Unlike local ones, these groups are structured around a common purpose or interest and encourage freer, more flexible, and more personalized forms of interaction (Awosusi et al., 2022; Namaziandost et al., 2021).

Park & Choi (2009) suggest that professional knowledge can be cooperatively constructed in digital contexts with the development of interactive technologies.

In addition, these networks support targeted learning and facilitate access to personalized content, depending on individual interests (Mendel, 2011; Dede et al., 2016). According to Holmes (2013) and McConnell et al. (2013), professional collaboration supported by digital platforms contributes to extending the duration and increasing the accessibility of lifelong learning. Xu et al. (2023) highlight that, within online communities, teachers' professional identities gain increased visibility, considerably influencing interaction patterns and perceptions of their own role.

4. Professional development programs and platforms in Romania

To respond to the challenges generated by the digital transformation of education, the European Union launched the strategic initiative *"Resetting Education and Training for the Digital Age"*. The Digital Education Action Plan (2021-2027) is one of the initiatives included in this program. This initiative is complemented by additional measures to support member states in transitioning to a modernized education system. One such measure is the intention to collaborate with the European Investment Bank to allocate funds for the development of digital educational infrastructure (European Commission, 2021).

Additionally, it is proposed that Erasmus+ programs be reviewed and adapted to explicitly include the digital education component. In this framework, digitalization is recognized as an essential legislative priority for strengthening the European education.

The related action plan aims at two main strategic directions: the integration of educational technologies in all levels and forms of education, as well as the development of digital skills among teachers, pupils and students (European Commission, 2022). These

objectives reflect the European Union's commitment to building a resilient, inclusive, and responsive educational ecosystem that adapts to the demands of the digital age.

In recent years, Romania has initiated several programs and initiatives dedicated to the continuous professional development of teachers to support the transition to an education system adapted to the new requirements. These include EDIS-PED, iTeach, and Aspire Teachers, as well as the strategic approaches under SMART-Edu. These programs aim to upgrade pedagogical skills through digital training and the production of open educational resources. These programs address the challenges posed by digitization and the need for curricular and methodological transformation in line with the principles of Education 4.0.

4.1. SMART-Edu

Romania's *SMART-Edu* Strategy (2021-2027) has developed action plans based on the two main areas included in the EU Digital Action Plan. The program offers a consistent set of measures to digitize the education system, focusing on equity, quality, and adaptation to contemporary societal demands. Major action lines include:

1. Strengthening digital competencies at all levels of education through specialized subjects, cross-curricular approaches, and formal and non-formal teaching activities.

2. Supporting the initial and in-service training of teachers in the digital domain to prepare them to integrate technology into teaching.

3. Modernizing the digital infrastructure of schools to reduce access inequalities by extending connectivity, developing internal networks, and providing modern equipment and technical support.

4. Facilitating the exchange of best practices among schools through local, national, and international e-learning platforms, such as SELFIE and eTwinning.

5. Promote cyber safety and responsible digital behavior initiatives with a focus on personal data protection, digital hygiene, and the ethics of technology use (MEC, 2020).

4.2. iTeach

In the context of the accelerated digitization of education, the *iTeach* platform is one of the most relevant Romanian initiatives dedicated to the continuous professional development of teachers. Developed by the Institute for Education and Social IT, *iTeach* operates as an all-in-one educational system for pre-university and university educators (iTeach.ro, 2024).

The platform provides access to short, accredited online courses that are recognized with transferable professional credits in accordance with Ministry of Education regulations. Users can also publish scholarly articles and open educational resources, which reinforces a collaborative framework based on open learning and knowledge sharing.

With over 11,000 educational resources and 6,000 articles in its database, *iTeach* provides access to relevant, up-to-date, and diverse content. Its interactive component is supported by educational social networking functionalities, including blogs, wikis, thematic groups, collaborative spaces, and videoconferencing tools.

The platform also promotes personalized learning through a digital mentoring system that provides teachers with individual and collective support for their professional development. Its interactive component is supported by educational social networking functionalities: blogs, wikis, thematic groups, collaborative spaces, and videoconferencing tools.

Additionally, the platform promotes personalized learning through a digital mentoring system that provides teachers with individual and collective support in their professional development.

Through this approach, *iTeach* supports not only the continuous professional development of teachers, but also the formation of active professional communities connected by shared objectives and online collaboration (Educatia-Digitala.ro, 2024).

4.3. EDIS-PED

The *EDIS-PED* (Digital Ecosystem for Sustainable Learning with Open Educational Resources and Practices) Program, is a strategic initiative aimed at training pre-university teachers in Romania. The project, which is launched in the 2024-2025 school year, is coordinated by the University of Bucharest and carried out in partnership with several Houses of the Teaching Staff (in Bucharest, Dâmbovița and Prahova) and the Constantin Brătescu Pedagogical College in Constanța. Funding is provided through the National Recovery and Resilience Plan (PNRR), and participation is free for public school teachers (Educatia-Digitala.ro, 2024).

The program's primary goal is to educate 3,100 teachers in digital pedagogy via intensive courses and specialized mentoring. Participants can choose between two training paths: a postgraduate program provided by the University of Bucharest or an accredited program equivalent to 25 transferable professional credits offered by partner institutions. Both training programs combine synchronous and asynchronous activities amounting to 78–96 hours and are conducted entirely online.

In addition to the theoretical training, *EDIS-PED* offers a practical mentoring phase of at least three months to facilitate applying knowledge to real teaching contexts.

Another outcome of the program is the creation of Open Educational Resources (OER), developed by the participants and considered for accreditation as official teaching aids.

The project targets teachers at all levels of pre-university education - from early education to post-secondary - with a special focus on teachers in rural or disadvantaged schools. Training groups are organized according to specialization, level of digital competence and institution of origin. Through this comprehensive approach, *EDIS-PED* contributes significantly to bridging the digital divide in education, supporting the professional development of teachers, increasing the quality of education and the effective use of digital resources in schools (Educatia-Digitala.ro, 2024).

4.4. Aspire Teachers

Since its launch in 2016, the *Aspire Teachers* program has become one of the most innovative models of teacher training in Romania. The organization's main mission is to connect education to the realities of the 21st century by helping teachers acquire critical thinking, emotional intelligence, and active learning skills.

A central pillar of *Aspire*'s work is the professional development of teachers, which is carried out through communities of practice, applied training, and scientifically validated pedagogical resources. By 2025, over 6,000 teachers nationwide had participated in the program's activities, positively impacting the education of around 20,000 students (AspireTeachers.ro, 2025).

Relevant professional development initiatives include DataMathLab, an annual program supporting secondary mathematics teachers with hybrid training sessions in regional centers such as Bucharest, Iași,

and Cluj, as well as thematic webinars and online workshops on instructional design, alternative assessment, flipped teaching, and student-centered learning. These initiatives complement in-service teacher training in a flexible and accessible way.

Aspire emphasizes collaborative support through active professional communities. Selected teachers participate in testing and validating resources, collaborating in learning groups and becoming part of a network to disseminate good practices. Aspire also provides one-on-one pedagogical mentoring to help strengthen teachers' professional identities.

In addition to direct training, *Aspire Teachers* has been involved in educational advocacy processes, proposing solutions to improve framework plans, curriculum provisions, and initial training policies. For instance, the organization the organization has supported the incorporation of digital literacy and data science into secondary education.

Aspire Teachers is thus an example of good practice in teacher professional development, offering a coherent, applied, teacher- and student-centered approach that contributes to transforming Romanian schools through competence, collaboration, and pedagogical innovation.

5. Conclusions

In the era of Education 4.0, which is characterized by the accelerated integration of technology into the learning process, the professional development of teachers has become a strategic necessity. The rapid changes brought about by the Fourth Industrial Revolution, including technologies such as artificial intelligence, augmented reality, and machine learning, require teachers to adapt and fundamentally redefine their role in education.

In this context, effective professional development practices involve in-service training, interdisciplinary collaboration, project-based learning, and integrating digital competencies.

For these initiatives to have a sustainable impact, professional development must be centered on teachers' real needs, be continuous and accessible, and be contextualized. Institutional support and coherent education policies must actively encourage teachers to participate in relevant training.

Romania's continuing professional development programs demonstrate a sustained effort to adapt education to the requirements of the digital era and the values promoted by Education 4.0. However, to ensure

the sustainable, coherent transformation of teacher training, strategic directions and concrete recommendations are needed.

First, access to free and flexible digital training programs must be expanded, especially for teachers in rural or disadvantaged areas where significant technology gaps still exist. These programs should systematically include Education 4.0 - specific competencies, such as personalized learning, integration of emerging technologies, and design of learner-centered learning environments.

Strengthening mentoring and post-training support is also essential for transferring knowledge into practice and encouraging pedagogical reflection. In this regard, creating active professional communities, whether physical or digital, can provide valuable spaces for teachers to collaborate, share best practices, and support one another.

Finally, teachers who actively engage in their professional development become agents of change and can contribute significantly to an education system adapted to 21st-century demands.

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