

RESEARCH PAPER

Potentialities of a Local Job Shadowing Experience in Initial Science Teachers' Training

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ABSTRACT

This paper describes a “job shadowing” initiative developed in the context of initial teacher education to promote awareness of the different dimensions present in science, technology, engineering, and mathematics (STEM) relationships. Ten pre-service teachers participated in this initiative, visiting three different contexts: A museum integrated within a school, an oceanarium, and a research center. After each visit, participants completed a learning diary and a checklist, designed to promote participants’ metacognitive thinking about the job they were observing and to identify the experienced utility of each visit. This experience seemed to have promoted a broader, more critical, and more integrated view of education, impacted participants’ motivation, professional awareness, and social commitment, and contributed to the strengthening of the vision of education as dynamic, interdisciplinary, and socially relevant, and of educational careers as flexible, multifaceted, and constantly evolving. This has important implications for STEM teacher education and professional development, highlighting the value of incorporating non-formal and research-based experiences into training programs to better prepare educators for the complexities of contemporary educational landscapes.

KEY WORDS: Initial teacher education; job shadowing; science, technology, engineering, and mathematics approach

INTRODUCTION

Over the past decade, there has been growing recognition of the need to equip educational systems to prepare students for the development of critical and analytical thinking, to boost competitiveness through the development of innovative ideas, and to motivate them to pursue careers in the field of science through a transdisciplinary approach across its various areas (Land, 2013). In light of this need, science education has come to prioritize the science, technology, engineering, and mathematics (STEM) approach, i.e., interdisciplinary teaching that integrates STEM into an integrated learning model, as a way to promote interdisciplinary knowledge, which has the potential to foster the ability to transfer knowledge across different scenarios (OECD, 2019). This approach to science education emerged in response to a need to foster students’ competitiveness and critical thinking. Its purpose is also to prepare students to address current and pressing technical and scientific issues that arise in our social context.

However, the transition from a traditional, compartmentalized, discipline-based educational structure to a STEM approach requires profound changes at the curriculum and lesson planning levels (Nadelson and Seifert, 2017). This challenge is compounded by the need for teachers to possess specialized knowledge across different disciplines, as well as pedagogical skills to teach this content effectively. In fact, teachers need

to acquire solid and in-depth knowledge of STEM areas; develop pedagogical skills to design effective teaching strategies such as inquiry-based, project-based, and problem-solving activities; promote integration across disciplines and the development of transversal skills; assess all these forms of learning; use digital tools and emerging technologies; encourage diverse participation in learning; and develop and integrate collaborative and innovative contexts and mindsets that reflect real-world STEM practice (European Commission [EC], Joint Research Centre et al., 2024).

To develop this educational capacity, it is necessary to consider innovative strategies for teacher education, particularly in initial training, that foster an understanding of integrated STEM teaching and learning as an open and continuously evolving process.

One strategy already identified by the European Union is the establishment of partnerships with universities, industries, or organizations related to STEM dimensions, for example through internships and/or “job shadowing” initiatives during initial teacher education. Indeed, many pre-service and in-service science teachers have limited opportunities to observe how scientific knowledge is applied across different sectors such as industry, research centers, and even science museums and other educational institutions.

Job shadowing, as an experiential learning approach, offers a structured means of addressing this gap by enabling

participants to observe professional practices directly, engage with organizational cultures, and reflect on diverse career possibilities.

A job shadowing initiative refers to the opportunity for an individual to directly observe a professional performing their duties in the workplace (Cho and Gao, 2009). In an educational context, job shadowing is defined as an opportunity for students to accompany an experienced employee while they perform their targeted or related job, allowing them to experience what it is like to do a particular job (Rony et al., 2019).

This paper describes a “job shadowing” initiative developed, on an exploratory basis, within the context of initial science teacher education. The initiative aimed to provide pre-service teachers with the opportunity to interact with professionals (educators and researchers) from different fields and to promote awareness of the various dimensions within the STEM relationship. The study aims to contribute empirical evidence on the role of job shadowing in supporting pre-service teachers’ development as STEM educators.

LITERATURE REVIEW

According to the more recent EU report on the STEM education strategic plan (EC, 2025), while education and training systems in the majority of European and OECD countries have already taken steps to raise awareness and support actions to improve STEM competences, a stronger focus on STEM education and training is essential to sustain competitiveness, preparedness, and technological leadership.

Although the STEM approach can accommodate multiple forms of conceptualization and operationalization, overall, the interrelationship between five structural dimensions is advocated (Bryan et al., 2015): (1) Integration of STEM content; (2) problem-centered learning; (3) inquiry-based learning; (4) design-based learning; (5) cooperative learning, which are organized to enable students to develop the learning competencies established for the 21st century, such as critical thinking, communication, collaboration, and creativity (Partnership for 21st Century Learning, 2022). One of the strengths of this approach lies in the integration of two important concepts, inquiry-based learning (Bybee, 2013), which is related to the development of projects aimed at solving problems encountered in daily life, and design-based learning (Ellefson et al., 2008), which assumes that students work collaboratively on the creation or design of a new invention or prototype, for which they must mobilize and apply scientific knowledge.

This transition from a traditional, segregated, and discipline-based educational structure to an integrated STEM approach requires profound changes in curriculum and lesson planning (Nadelson and Seifert, 2017). Integrated STEM education demands extensive resources, including materials and human capital, such as teacher training and development. This challenge is compounded by the need for teachers to have

specialized knowledge in STEM disciplines and pedagogical skills to teach this content effectively. And so, STEM educator capacity building is being increasingly recognized as an important aspect within STEM education and policy.

The European Union has already identified some key components of capacity building that must be strengthened by STEM teachers, namely those related to curriculum, pedagogy and assessment, such as content knowledge, pedagogical skills, technology integration, assessment literacy, leadership, collaboration and inclusion (Abrams et al., 2021; Ni et al., 2023; Wachira and Klinger, 2023). Indeed, STEM teachers need to acquire strong and deep content knowledge in STEM subjects, to use digital tools and emerging technologies (e.g., coding, robotics, and data analysis), and to develop pedagogical skills for developing effective teaching strategies, such as inquiry-based, project-based, and problem-solving activities. Moreover, they need to foster integration across disciplines and the development of transversal skills, and to evaluate all these learnings. Finally, to ensure all this, they need to develop and be involved in collaborative and innovative mindsets and contexts that reflect real-world STEM practice (EC, Joint Research Centre et al., 2024).

However, many teachers feel underprepared to implement STEM applications, indicating a significant gap in teacher training and resources (Nadelson and Seifert, 2017; El-Deghaidy and Mansour, 2015). To build this education capacity, the European Union has been designing different programs, strategies, and initiatives aligned with a new vision of teachers’ professional development that is likely to foster more of a growth mindset and understanding of teaching and learning integrated STEM as being more open-ended. These programs, such as advanced workshops and training programs, are focused not only on STEM subjects, but also on pedagogical strategies to implement inquiry-based learning, design thinking, and computational thinking, to align capacity building with broader transitions (digital, green) to make education future-oriented. Examples of this actions are: Combining face-to-face training with MOOCs/online courses; Professional Learning Communities for continuous peer support (Erasmus+ “Teacher Academies”), to foster interdisciplinary pedagogies, inclusive teaching, gender balance, and novel assessment methods in STEM; action research projects that allow teachers to experiment and reflect on their own practices (school-based STEM centers/hubs); continuous professional development frameworks aligned with national education goals (micro-credential and innovation courses); and mentorship and coaching from STEM experts, through partnerships with universities, industries, or STEM organizations (experiencing professional internships and/or job shadowing initiatives).

Among such initiatives, short-term, national or international mobility programs, such as mentorship, collaborative learning communities, or job shadowing initiatives (for a review, see Bourke et al., 2024), have gained attention across the world

considering their potential to enhance educators' professional and interdisciplinary awareness (Citci and Karaman, 2019). These short-term initiatives, which typically last from a few days to a few weeks, have a greater focus on enhancing educator capacity related to STEM educational practices, in particular those related to the curriculum, pedagogy, or assessment practices, via exposure to inter-cultural and inter-disciplinary STEM practices, and inter-organizational orientation (Makkai-Kovács and Kardos, 2023).

In general, science teachers, despite being exposed to extensive STEM-related scientific knowledge during their training, often have limited opportunities to observe how this theoretical knowledge is concretely connected to other disciplines and institutional practices in real-world settings. This deficiency creates a gap in the active use of acquired knowledge and in the development of a vision for multidisciplinary working environments among teachers and teacher candidates (Cavas and Mercan, 2025). All these initiatives, through involving teachers in experiencing interdisciplinary working environments, and field-based research processes, aimed to contribute to helping teachers to improve students' engagement, participation, and accomplishments in STEM disciplines, to provide students with more opportunities to engage with competent and influential STEM educators and leaders, to tackle and narrow the disparities in students' STEM talent and skills, and to build community awareness and support for STEM learning (EC, Joint Research Centre et al., 2024).

Despite the promise of these short-term mobility programs, such as job shadowing initiatives, there remains a need for systematic research to understand the impact of such interventions on STEM educator capacity, as emphasized in the external study report prepared for the Joint Research Center (EC et al., 2024). As the global economy continues to evolve and everyday life changes due to technological development, the necessity for STEM skills becomes more critical than ever. For this reason, there is an urgent need for continued research into effective educational strategies and enhanced communication of STEM benefits to students and teachers, to address existing disparities in STEM talent distribution and to increase public support for STEM initiatives, crucial aspects needed for promoting equitable access to education and career opportunities.

METHODOLOGY

In this work, a "job shadowing" initiative that involved pre-service science teachers is described and analyzed, considering the participants' perspectives related to its main impacts in supporting their development as STEM educators. This exploratory study adopts a qualitative approach (Miles and Huberman, 1994) to gain insight into participants' experiences and views.

Context of the Study

The study was conducted within the Erasmus+ project AcaSTEMy (Teacher Academy 2023–2026) (<https://www.acastemy.eu/>).

The AcaSTEMy project involves nine universities from eight European countries (Croatia, Estonia, Finland, Germany, Hungary, Latvia, Portugal, and Turkey). Based on teachers' reported gaps regarding their digital skills, sustainability, equality, and inclusivity, the project aims to develop a systematic support structure for high-quality, research-based STEM teacher training.

The AcaSTEMy local job shadowing model provides teacher educators and pre-service teachers with opportunities to deepen their understanding of contemporary STEM education through participation in authentic educational, research, and workplace environments. The concept is grounded in peer learning and professional observation, enabling participants to follow and reflect on the work of experts in universities, research laboratories, science centers, museums, and industry.

Job Shadowing Description

In the Portuguese context of research-based teacher education, job shadowing is intended to support pre-service teachers' professional agency, strengthen the interface between education, research, and working life, and promote the development of STEM education that foregrounds transversal competences, sustainability, and societal relevance.

For this initiative of job shadowing, pre-service students from two teacher education institutions, were invited to voluntarily participate in three half-day visits to three distinct locations: A School Museum (MUESC), with a historical archive and exhibition space, a museum institution focused on promoting ocean literacy (Lisbon Oceanarium), and a Research Centre focused on food sustainability and the production of new foods (LEAF - Linking Landscape, Environment, Agriculture and Food Research Centre). In each visit, participants had the opportunity to engage with professionals in each context, following their daily work. Ten pre-service students took part in this initiative. They were all pre-service teachers. Some of them were students in the Master's Degree in Teaching Biology and Geology at the Upper Elementary and Secondary Levels (4 from the 1st year and 3 from the 2nd year), and three were students in the Master's Degree in Teaching for the First Cycle of Basic Education and in Mathematics and Natural Sciences for the Second Cycle of Basic Education (1st year).

Day 1. School museum (MUESC)

This museum has as its main objectives the conservation and study of the historical educational objects (books, manuscripts, films, specimens, and scientific instruments) present in the school. This large school heritage collection represents the Portuguese school functioning since the beginning of the 19th century. This school museum serves as an open space, not only for the whole school community, but also for the surrounding community.

At the beginning of the visit to the school museum, participants had a meeting with the teacher (who is also the museum curator) responsible for this space, who gave detailed information about the functions of the museum. She also detailed the different

tasks involved in its organization and function and the support mechanisms available to students and teachers. In the case of students, some of them are volunteers to work in the museum, and others use the collections available for their own research and school work. On the other hand, teachers use the museum for preparing their own activities and lessons. After that introduction, participants had the opportunity to visit all parts of the museum, the public areas and the non-public ones (that are yet in the process of organization and cataloging), and to talk to those who work there (teachers and volunteer students). During this second part of the visit, they had the opportunity to understand how a museum focused on the artefacts and history of public schools in Portugal is used and explored in depth in today's education system, particularly by the students themselves, who are researching the use of certain scientific instruments in teaching.

Day 2. Lisbon oceanarium

At the beginning of the visit to the oceanarium, participants had a meeting with the biologist responsible for the educational sector of this aquarium, who gave detailed information about the functions of the institution, the different tasks involved in its organization, in particular those related to school visits. After that introduction, they had the opportunity to visit all parts of the aquarium and to accompany one of the scheduled study visits for that day by different schools, guided by a museum monitor. Through this observation of school field trips, participants had the opportunity to observe and better understand how the visit is conducted, and how the aquarium's resources are used to explore scientific topics and issues related to ocean conservation.

Day 3: Research Center on new forms of food (LEAF)

During the visit to the research center related to food sustainability and the production of new foods (LEAF), the participants were first provided by the coordinator of the research center with detailed information about the functions of the research centre and the support mechanisms available to researchers. In this context, they were introduced to the support offered for project funding services, guidance on patenting and registration processes, research and development, and university-industry collaborations. Following this briefing, the participants were taken to different laboratories to gain insights into the instruments and research procedures used to develop new forms of food. During these visits, they had the opportunity to see some of these technical instruments operating and to hear from the researchers present about the main objectives, advances and challenges involved in each research project.

Data Collection and Analysis

After each visit, all participants completed a checklist and a learning diary. The checklist was designed to promote participants' metacognitive thinking about the job they were observing. This instrument is designed in a semi-open, written format with three parts: Things that meet your eye; What do these things tell you about yourself? Beyond what meets the

eye. In the first section, they were asked to think about the job they are observing (e.g. main tasks involved, skills needed, background training needed, and main challenges it involves); in the second section, they were asked to compare the job they are observing with their own future job (e.g. similarities and differences considering skills and challenges); and in the final section, they were asked to think about what they will do differently if they had the same job, what do they take to their own job, and how the experience impacted their vision about their job and the world in general.

The purpose of the learning diary has been to identify the experienced utility of each visit. It is composed of six open-ended questions related to their opinion about the job or the job-shadowing experience (what they found interesting, what they found boring, what they found useful, what they found unnecessary, any other ideas or thoughts about careers based on the experience lived that day, any other thoughts). In this diary, participants were asked to write their experiences, with specific examples from each day.

For analyzing the data, a thematic analysis method was used (Almeida, 2026). After reading all the written answers (familiarization step), the main dimensions of analysis were defined through the identification of segments of data relevant to the objectives of this study (generating initial codes step). In a third step, through an iterative process of reading and re-reading data, these initial codes were assigned to potential themes through the identification of emerging topics (searching for themes step). Finally, these themes were refined through a critical review to check if they work in relation to the different meanings present (reviewing themes step).

All participants previously gave written consent for participation in the study.

RESULTS

The analysis of the reflections reveals a set of learning outcomes achieved by the pre-service teachers regarding their conception of education, the importance of the educational heritage and school identity, and the role of science in their relation to society and education. The thematic analysis of participants' responses revealed a significant transformation in perceptions of careers in education. Across all contexts, there is a clear expansion of the concept of the educational career, traditionally associated with classroom teaching.

In the Museum context, participants highlighted a rediscovery of education as a situated practice mediated by educational heritage, emphasizing the possibility of teaching through historical objects, archives, and institutional memory (*"teaching through the living history of a school, through the objects that tell that story"* [A., MUESC]). Indeed, this visit appears to have fostered a strong appreciation for memory and educational heritage as fundamental elements in the construction of individual and collective school identity. The school museum emerges as a living space that goes beyond

preservation to act as a mediator of meanings, identities, and a sense of belonging to public education, as illustrated in the following excerpts:

“It reinforced the idea that school can be much more than classes and tests. It can be a space of memory, identity, and creation.” (B., MUESC)

“I would like to add that this visit to MUESC made me rethink what teaching is. We often associate education with the classroom, the board, and the textbook, but here I realized how teaching can also happen through the living history of a school, through the objects that tell its story and the memories they hold. There is something very special about working with this type of heritage, because it is not just about organizing or preserving – it is about giving it a pedagogical purpose. (...) It is a way of teaching that inspires me and makes me want to be a more creative educator, more connected to reality and to the history of schools and students. (...) I truly felt that I left there different – more motivated, more curious, and more aware of what I want to carry with me into the future.” (A., MUESC)

This experience fostered a reconfiguration of the teacher’s role, which is no longer seen merely as content transmission but rather as cultural mediation and meaning-making. At the same time, new professional possibilities emerge, such as curatorship and collection management, and their potential role as educational mediators, giving support and complementing the role traditionally assumed by the teacher.

In the case of the oceanarium, education was associated with non-formal contexts characterized by strong experiential, interactive, and multisensory components. Pre-service teachers also demonstrated important learning related to the pedagogical potential of these types of contexts. These experiences were seen as an added value for curriculum development, enabling future teachers to bring students closer to topics such as sustainability, as presented by one of the participants:

“This experience impacted my way of thinking, making me even more aware of the urgency of understanding the ocean to preserve it. In addition, I was very pleased to learn about the wide range of educational opportunities offered by the oceanarium, allowing me to further develop curricular content through study visits with my future students to this place.” (G., oceanarium)

Participants emphasized the role of education in changing behaviors, building environmentally conscious citizenship, and addressing environmental and social challenges. Science was perceived as inseparable from education and as something that must work together with it to promote a more informed, active, and responsible society, as illustrated by the following excerpt:

“It made me reflect on the role of education in changing behaviors and building a more aware and active generation.” (B., oceanarium)

At the end, participants valued the role of educators as science communicators (*“educators as expert guides and science*

communicators” [H., oceanarium]), capable of adapting content to diverse audiences and promoting meaningful learning outside the traditional classroom environment. This context also stands out for introducing new professional areas, such as educational tourism and science communication, highlighting the growing intersection between education, science, and society.

In turn, the scientific research context contributed to deconstructing stereotypical views of scientific work, often associated with rigidity and excessive specialization. Their accounts highlight the value of the visits as privileged opportunities to engage with real contexts of knowledge production and scientific innovation:

“It showed me that science and education must go hand in hand to face environmental and social challenges.” (B., LEAF)

Participants emphasized the creative, dynamic, and interdisciplinary nature of research (*“Scientific fields do not operate in isolation”* [S., LEAF]), recognizing the articulation between different scientific fields, such as chemistry, biology, and the food sector, challenging the traditional view of research as something purely technical.

Moreover, the social impact of science was strongly highlighted (*“science as a tool for social change”* [H., LEAF]), particularly in relation to sustainability and food innovation, often associated with addressing global challenges and contributing to future generations’ well-being. This context also revealed the diversity of professional roles, including research, coordination, quality control, and technical services.

The comparison across the three contexts allows for the identification of a conceptual progression in participants’ representations. While the MUESC emphasized education grounded in the interpretation and valorization of the past, the oceanarium promoted learning based on experience and science communication, and the LEAF science research context highlighted education oriented toward knowledge production and application.

Indeed, pre-service teachers demonstrated important learning related to the pedagogical potential of non-formal contexts, such as museums and research centers. Their accounts highlight the value of these visits as privileged opportunities to engage with real contexts of knowledge production. These experiences were seen as an added value for curriculum development, enabling future teachers to bring students closer to topics such as sustainability, research, and scientific innovation, as illustrated below:

“This experience impacted my way of thinking, making me even more aware of the urgency of understanding the ocean to preserve it. In addition, I was very pleased to learn about the wide range of educational opportunities offered by the oceanarium, allowing me to further develop curricular content through study visits with my future students to this place.” (G., oceanarium)

Participants also emphasized the role of education in changing behaviors, building environmentally conscious citizenship, and addressing environmental and social challenges. Science was perceived as inseparable from education and as something that must work together with it to promote a more informed, active, and responsible society, as illustrated by the excerpts below:

“It made me reflect on the role of education in changing behaviors and building a more aware and active generation.” (B., Oceanarium)

“It showed me that science and education must go hand in hand to face environmental and social challenges.” (B., LEAF)

All visits seemed to have contributed to the development of a broader conception of teaching that integrates mediation, experience, and innovation, promoting a more flexible, interdisciplinary, and context-sensitive view of education, reinforcing the role of teachers as agents of innovation. These spaces were valued as flexible educational resources that can be integrated into teaching practices, allowing for diversification of methodologies, enrichment of curricular content, and the promotion of more engaging, active, and meaningful learning, as illustrated below:

“It was very interesting to understand how museum work can be articulated with the pedagogical dimension. I found particularly relevant the way the connection between the school’s past and its present students is promoted. I highlight the critical perspective underlying the selection of certain objects, such as the plaque referring to the ‘head of minor staff’ or the exhibit dedicated to what it meant to be a student who challenged authority. In other words, the ability to go beyond the mission of preserving memory and also question it.” (B., MUESC)

In addition, interdisciplinarity emerged as a common structuring axis across all three contexts. Similarly, the development of transversal competencies, such as collaboration, creativity, critical thinking, and adaptability, was consistently valued and frequently associated with participation in projects and non-traditional educational settings.

In summary, the results indicate that the job shadowing experiences contributed to a significant reconfiguration of participants’ perceptions regarding careers in education (e.g., science center educator, school museum curator) and science. Rather than merely identifying new professions, participants appeared to have developed a more complex, flexible, and contextualized understanding of what it means to be an educator or a scientific professional in contemporary society, recognizing the multiplicity of contexts, roles, and impacts associated with these fields, and emphasizing the importance of the connection between science, society, and education.

All three contexts seemed to have served as complementary levels of understanding education and careers. The School Museum experience broadened the concept of teaching; the Oceanarium experience diversified the educational contexts;

and the Research Centre linked education to innovation and the future. Altogether, they seemed to have provided a very meaningful job shadowing experience, providing a vision of education as dynamic, interdisciplinary and socially relevant, and of educational careers as flexible, multifaceted and constantly evolving.

DISCUSSION

The experiences described appear to have had a clear impact on the construction of the auto-perception of pre-service teachers as STEM educators. Participants reported feeling more motivated, inspired, and aware of the type of educators they wish to become: More creative, critical, and connected to reality, history, and students’ needs. There was also the recognition of alternative career paths within education beyond traditional teaching, broadening vocational horizons.

Indeed, the data obtained in this study suggest that, through this job shadowing experience, participants engaged in processes of reflection-on-action, critically reassessing their assumptions about teaching, learning, and professional roles. This reflective process is particularly evident in the ways participants articulate intentions to integrate new approaches into their future practice, such as incorporating interdisciplinary projects, using material culture in teaching, or engaging with external educational institutions.

Importantly, the three contexts together illustrate a progression that resonates with contemporary discussions on what it means to be a STEM educator, recognizing the multiplicity of contexts, roles, and impacts associated with these fields, and emphasizing the importance of the connection between science, technology, society, and education. Indeed, participants seemed to consistently value learning situations that were grounded in real-world engagement, interaction, and continuity between knowledge and lived experience.

The movement from the MUESC (school identity-based mediation), to the oceanarium (science communication in non-formal settings), and finally to the scientific research center (knowledge production and innovation), promoted an increasingly complex and expansive understanding of what it means to be a science educator or science professional. This trajectory aligns with current perspectives that emphasize hybrid professional roles, where boundaries between teaching, communication, research, and societal engagement are increasingly blurred (EC, Joint Research Centre et al., 2024).

Another key aspect highlighted by the findings is the centrality of interdisciplinarity, which is consistent with current educational reports that advocate for integrated approaches to knowledge (OECD, 2019; UNESCO, 2015). Participants’ recognition of the interconnectedness of scientific disciplines and their relevance to real-world challenges aligns with what contemporary literature frames as the need for transdisciplinary competencies in addressing complex global issues (EC, 2025).

CONCLUSION

The findings suggest that exposure to diverse educational contexts can play a crucial role in fostering reflective, flexible, and interdisciplinary conceptions about STEM teaching. By engaging with environments that embody experiential learning, contextualized meaning-making, and reflective practice, participants were able to develop a more nuanced understanding of education as a multifaceted and socially embedded practice.

Overall, this experience seems to have promoted transformative learning among pre-service teachers, fostering a broader, more critical, and integrated view of education, and positively impacting their motivation, professional awareness, and social commitment, thus reinforcing the idea of a more open, contextualized, and meaningful education. This has important implications for STEM teacher education and professional development, highlighting the value of incorporating non-formal and research-based experiences into training programs to better prepare educators for the complexities of contemporary educational landscapes.

As emphasized by Cavas and Mercan (2025), the systematic incorporation of practice-based models, like these job shadowing experiences, that thrive on the interconnectedness between science education, societal well-being, and technological advancement, into national teacher education practices should enhance the innovation and entrepreneurship capacities of both teachers and their students.

LIMITATIONS

This study has several limitations that should be considered when interpreting its findings. First, participation in the job-shadowing program was voluntary, which may have introduced volunteer bias, as participants were likely to be more motivated and receptive to professional learning than the broader population of pre-service teachers. Second, the reliance on self-reported data may have been influenced by social desirability bias, with participants potentially providing more favorable accounts of their experiences and perceived learning. In addition, the qualitative content analysis was conducted by a single researcher, which may have increased the risk of subjective interpretation despite the systematic coding procedures adopted throughout the analysis. The relatively short duration of the intervention also limited the opportunity to examine how the reported benefits translated into sustained changes in teaching practice. Furthermore, the context-specific nature of the study restricts the transferability of the findings, as the outcomes may have been shaped by the particular institutional, cultural, and educational settings in which the job-shadowing activities were implemented. Finally, the absence of follow-up data prevented an assessment of the long-term impact of the experience on participants' professional development and classroom practices. Future research should address these limitations by including more diverse samples, involving multiple researchers in the qualitative analysis to enhance credibility, incorporating longitudinal designs,

and examining the extent to which the reported benefits are maintained and transferred across different educational contexts.

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