

Enhancing teachers' TPACK for data science in STEAM education: Insights from a pilot professional development program in Cyprus

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In today's data-driven world, education systems face growing pressure to equip students with data science literacy and critical thinking skills. While STEAM education offers a natural interdisciplinary setting for fostering these competencies, teachers often lack the confidence, training, and pedagogical strategies needed to integrate data science into their practice. The EU-funded DataScEd4CiEn project responds to this challenge by designing and implementing a Professional Development (PD) program tailored mostly for STEAM educators. This paper presents an exploratory study of a pilot implementation in Cyprus, aimed at investigating how the program supports teachers in adopting data-driven, interdisciplinary approaches. Using a Design-Based Research (DBR) methodology, the study iteratively refines the PD model while collecting mixed-methods data to examine changes in teacher knowledge, instructional practices, and collaborative engagement. Preliminary findings highlight the transformative potential of targeted PD in advancing data science integration and empowering teachers to meet the evolving demands of 21st-century education.

INTRODUCTION

The increasing ubiquity of data and Artificial Intelligence (AI) across society highlights the urgent need for data science literacy in education. As Wing (2019) argues, the ability to work with and critically interpret data is a cornerstone of modern, informed citizenship. Despite this, current school systems often fall short in providing students with opportunities to meaningfully engage with real-world, complex data. A key challenge lies in the limited integration of interdisciplinary approaches—such as STEAM (Science, Technology, Engineering, Arts, and Mathematics) education—that are well-suited to fostering data literacy and civic engagement. This challenge is compounded by the fact that many teachers lack the preparation and thus confidence in embedding data science into their instructional practices (Wineburg et al., 2016).

The DataScEd4CiEn project (Data Science Education in STEAM for Civic Engagement and Social Justice from the Early Years), funded by the European Union under Erasmus+ KA2, aims to support this gap by supporting educators in using data science as a tool for promoting civic engagement and social justice. The project has designed a PD program and curricular resources that integrate data science literacy, AI, and ethical inquiry into STEAM education for learners aged 9–15 across five European countries. Using a design-based research approach (Cobb et al., 2003), the PD model is iteratively refined and tested across five European countries: Cyprus, Germany, Greece, Ireland, and Spain.

This paper presents findings from the first round of pilot implementation of the DataScEd4CiEn professional development (PD) program at the English School in Cyprus. The study examines the effectiveness of a structured, modular PD framework designed to enhance teachers' capacity for data-driven STEAM instruction. It investigates how such an approach can support teacher learning and the integration of data science into existing curricula. Specifically, the study addresses the following research questions:

1. How does the PD program influence teachers' readiness to integrate data science into STEAM education?
2. What challenges do teachers identify when applying data science to support civic- and justice-oriented STEAM teaching?

METHODOLOGY

Participants and Context

The PD program at The English School in Nicosia was delivered in two phases during the 2024–2025 academic year as part of the DataScEd4CiEn project. Phase one, conducted in November 2024, involved a broad cohort of 46 teachers from all departments, introducing core concepts related to STEAM and data science while promoting interdisciplinary collaboration. Phase two, held in February 2025, engaged a smaller, strategically selected subgroup of 11 teachers—chosen from those who had already participated in Phase 1—representing key subject areas including Mathematics, Science, Computer Studies, Geography, English, Design and Technology, and PSHCE (Personal, Social, Health and Citizenship Education). This group included specialist teachers and department coordinators—teachers appointed within each subject department to support STEAM-related initiatives across the school—who were responsible for adapting instructional practices and overseeing the pilot implementation in their respective departments.

The two-phase model allowed for differentiated engagement: the first phase built a shared foundational understanding across the school, while the second provided targeted support for implementation of new practices. Across both phases, the PD emphasized collaborative planning, integration of data science into disciplinary teaching, and engagement with socially relevant, real-world issues through inquiry-based pedagogy. This foundation set the stage for a structured, content-rich PD program designed to support both conceptual understanding and practical application, as detailed in the following section.

PD program structure and content

The PD program was organized into five interconnected modules across the two phases. Module topics ranged from introducing the project’s transdisciplinary framework and STEAM pedagogy to hands-on practice with data analysis tools and AI concepts, and finally to collaborative design of interdisciplinary lessons. In Phase 1, the focus was on building foundational understanding of STEAM, data science literacy, civic engagement, and inquiry-based pedagogy. Phase 2 provided more intensive training in using data science tools (e.g., CODAP and Gapminder), basic machine learning concepts, and discussions of AI ethics and bias, while guiding teachers in co-designing STEAM teaching scenarios. The training sessions were delivered through case-based discussions, live demonstrations of digital tools, collaborative lesson design workshops, and guided reflections.

In designing the PD content, facilitators took into account the background and needs of the participating teachers. Consistent with the literature on effective PD emphasizing contextual relevance (Desimone, 2009; Darling-Hammond et al., 2017), a pre-PD survey was used to gather teacher input and tailor the module content. This responsive approach ensured alignment between the training activities and the specific contexts of the teachers.

Data Collection and Analysis

To evaluate the impact of the PD program on participating teachers’ knowledge, attitudes, and pedagogical readiness, we employed a mixed-methods approach combining quantitative and qualitative data sources. This approach provided a comprehensive understanding of the outcomes and processes of the pilot implementation.

Surveys: Pre- and post-PD surveys were administered to measure changes in teachers’ self-reported confidence, conceptual understanding, and readiness to implement data science instruction. The surveys included Likert-scale items (e.g., rating agreement with statements such as “Indicate the extent to which you feel prepared to teach STEAM”) and a few open-ended questions. All 46 teachers from Phase 1 completed the pre-PD survey (and a post-PD survey administered after the initial training), and the 11 Phase 2 teachers completed a post-PD survey following the extended training. We analyzed the survey responses by comparing pre- vs. post-PD ratings and calculating the proportion of respondents indicating positive shifts on key measures.

Reflective Narratives: Reflective narratives were collected from participants during and after the professional development sessions to capture qualitative insights into their experiences, perceived challenges, and learning gains. These reflections were documented and analyzed for emergent themes

related to teacher confidence, conceptual clarity, integration of new content, and the relevance of the training to their instructional practice.

Workshop Artifacts: Artifacts from the scenario design workshops – including lesson planning templates, scenario drafts, and instructional materials created by the teachers – were gathered to assess how participants translated PD principles into concrete classroom practice. We reviewed these artifacts for evidence of data science integration (use of datasets, data analysis tasks, etc.), interdisciplinary collaboration (cross-subject links in lesson plans), and attention to ethical or civic dimensions introduced in the PD.

For the purposes of this analysis, we draw on the preliminary data from the surveys, reflective narratives, and design artifacts. Triangulating these sources provides an initial picture of the PD program’s effectiveness in shifting teacher attitudes and practices.

Implementation Phases

Following the Phase 2 training, the school team proceeded to co-design interdisciplinary teaching scenarios as the practical culmination of the PD. In early March 2025, a one-week coordination period was held during which departmental coordinators worked together to finalize the structure and content of the planned lessons. This collaborative planning stage aimed to ensure alignment and coherence across subject areas, so that the resulting instruction would be an integrated effort rather than a series of isolated departmental lessons.

The pilot teaching of the new scenario began in mid-March 2025 and was scheduled to conclude by the end of May. The sequence of subject contributions was deliberately structured to build students’ understanding progressively. The PSHCE department introduced the overarching theme, followed by lessons in Mathematics, Science, Computer Science, English, Art, and Design & Technology, each contributing distinct aspects of the learning experience. This progression ensured continuity and highlighted the truly interdisciplinary and collaborative nature of the project. Such a systemic approach aligns with contemporary calls for connected, authentic learning experiences that mirror the complexity of real-world challenges (Honey, Pearson, & Schweingruber, 2014; National Research Council, 2012).

RESULTS

Participant Profile and Initial Needs

The pre-PD survey revealed important characteristics of the teacher cohort that influenced the PD design. The group consisted largely of mid- to late-career educators, with approximately 70% (n=32) aged between 31 and 50, and about 63% (n=29) having more than 11 years of teaching experience. The vast majority—84.8% (n=39)—also held postgraduate degrees. This high level of experience and education provided a strong foundation of pedagogical knowledge and professional maturity. At the same time, while 78.3% (n=36) of teachers reported feeling confident in their use of classroom technology (indicating high digital competence), 43.5% (n=20) indicated unfamiliarity with the concept of STEAM education. This finding underscored the need to introduce and clarify STEAM principles in the training. These insights aligned with established principles of effective PD, emphasizing the importance of tailoring content to teachers’ backgrounds and prior knowledge (Garet et al., 2001; Guskey, 2002; Kennedy, 2016).

In response to the identified needs, the Phase 1 training included dedicated sessions on foundational STEAM concepts, with adjustments to allow more time for conceptual clarification and collaborative discussion. These strategies are consistent with best practices in professional learning (Desimone, 2009; Avalos, 2011). Post-training evaluations conducted immediately after the November 2024 session indicated a marked improvement in participants’ understanding of key concepts and their readiness for further engagement. According to the post-PD questionnaire, 60.9% (n=28) of participants reported that the professional development was relevant to their everyday teaching practice, and 84.8% (n=39) stated that the sessions were instrumental in helping them understand the project’s aims and content. These results underscore the effectiveness of the initial PD phase in bridging knowledge gaps and aligning participants with the project’s interdisciplinary goals (Desimone, 2009).

The design of the second PD phase (February 2025) deliberately built on the outcomes of Phase 1. More time was allocated to collaborative work and practical application, including hands-on activities with digital tools, interdisciplinary lesson planning, and structured discussions around the ethical and

civic dimensions of data science education (Gutstein, 2006; Engel, 2017). Post-PD survey results from this phase showed that 8 out of 11 participants felt the Phase 2 course design and materials would be helpful in planning their teaching. Additionally, 8 participants indicated that their perspective on teaching data science had changed as a result of the program, and 7 participants reported a similar shift in their perspective on teaching for civic engagement and social justice.

Of particular note was the shift in participants' understanding of the STEAM approach. In the pre-PD survey, 43.5% (20 out of 46 teachers) reported unfamiliarity with STEAM education. While the post-PD responses come from a smaller, more targeted group, 72.7% (8 out of 11 participants) in Phase 2 indicated that their perspective on STEAM teaching had changed. Although the two groups are not directly comparable, this suggests a promising trend in increased awareness and engagement with STEAM principles among those most actively involved in the pilot implementation. This suggests that the strong emphasis on STEAM fundamentals in the first phase was effective in fostering conceptual clarity and engagement (Guskey, 2002). The progression from unfamiliarity to a more evolved pedagogical perspective illustrates the importance of sustained, context-responsive professional learning that builds on teachers' prior knowledge and expands their capacity for interdisciplinary integration.

Classroom Scenario Development

Changes in teachers' understanding of data science concepts and their pedagogical application became most evident in the interdisciplinary teaching scenarios they co-developed and implemented during the pilot phase. Two such scenarios were designed: one focused on the causes and consequences of food waste, and the other on the social and environmental impacts of the fashion industry. The analysis that follows focuses on the latter— "*What is the True Cost of My Clothes?*" (A Social Justice and Data-Driven Approach to Fast Fashion)—as a representative example of the professional development program's impact.

This scenario was designed to explore the intersection of consumer behavior, environmental sustainability, and labor rights. It used real-world datasets to engage students in ethical analysis and data interpretation and was piloted with two Year 8 classes (53 students in total). In this cross-curricular unit, students analyzed data related to the fashion industry (e.g., production volumes, water use, and labor conditions) and examined the ethical issues associated with fast fashion.

Teachers integrated multiple subjects into the scenario: mathematical activities involved statistical analysis of fashion-related data, where students also became familiar with basic data science techniques such as filtering, grouping, and summarizing data; science lessons addressed the environmental impacts of textile waste; and humanities components—particularly in PSHCE and English—prompted discussions and written reflections on consumer ethics and global labor practices. Through this scenario, students gained experience in formulating their own questions, working with real datasets, and critically reflecting on the societal implications of their findings.

The process of designing and implementing the Fast Fashion scenario reflected a significant evolution in the teachers' pedagogy. The teachers not only selected and adapted reliable datasets related to the topic but also created a variety of supporting materials—including interactive presentations, data-rich handouts, and cross-curricular writing prompts—to facilitate student learning. During the implementation, students were guided through exploring and interpreting real data, and they engaged in inquiry-driven and creative tasks, such as designing their own upcycled clothing items based on data insights. This approach marked a clear advancement from the teachers' prior practice; it demonstrated that they had moved beyond introductory familiarity with data science concepts to achieve a functional and innovative application of data science in an authentic context. In particular, the successful enactment of the Fast Fashion project indicated not only improved conceptual understanding among the teachers but also a growing confidence in facilitating complex, interdisciplinary learning experiences for their students.

Table 1 summarizes the key pedagogical design features of the Fast Fashion scenario, including its learning objectives, interdisciplinary scope, civic focus, use of data tools, student inquiry elements, and assessment methods.

Table 1. *Pedagogical and design features of the “Fast Fashion” pilot scenario*

Aspect	Fast Fashion Scenario (Year 8)
Learning Objectives	Develop students’ ethical awareness; apply data science reasoning to real data; analyze the environmental and labor impacts of the fashion industry.
Interdisciplinary Integration	Multi-subject collaboration involving PSHCE for ethics and social awareness, Mathematics for data analysis, Science for environmental science content, English for narrative and reflective writing, Art & Design and Technology for creative design projects, and an ICT component for technical tasks (e.g., developing a website or AI-generated video as part of the project).
Civic/Social Focus	Emphasis on consumer ethics, global labor practices, environmental sustainability, and personal responsibility in consumption.
Data Science Tools Used	CODAP (Common Online Data Analysis Platform) was used for data visualization and analysis of clothing production and waste datasets. Students also formulated and investigated their own statistical questions related to the data.
Student Inquiry & Agency	Students took an active inquiry role: they generated their own research questions, analyzed authentic datasets, and proposed solutions. For example, they designed upcycled fashion products based on data findings to demonstrate sustainability in action.
Assessment Methods	A combination of written reflections, peer presentations, visual documentation of student-created products (upcycled clothing designs), and a cross-curricular group showcase event.

Teacher Feedback and Reflections

Qualitative feedback from participants further illuminates the impact of the PD. When asked which aspects of the program they found most valuable or would like to explore further, many teachers highlighted the direct applicability of the training to their specific subject teaching. Several noted that tools like CODAP were particularly useful for enriching mathematics lessons, especially by enabling the integration of real datasets into classroom practice. Others emphasized the significance of learning how to access reliable data sources and appreciated the opportunity to explore ways of meaningfully incorporating artificial intelligence into student projects. Such reflections affirm the value of practical, discipline-relevant applications in teacher professional learning (Avalos, 2011).

At the same time, the feedback pointed to areas for improvement. A number of teachers expressed a desire for additional time to practice using CODAP and to engage more extensively in peer collaboration before designing their own teaching scenarios. While the PD was positively received overall, these comments suggest that future iterations of the program could benefit from allocating more time for hands-on tool exploration and collaborative planning. Such enhancements would likely support deeper engagement with the digital and civic dimensions of STEAM, reinforcing the iterative, reflective nature of effective PD (Borko, 2004; Kennedy, 2016).

In sum, the combination of quantitative outcomes and qualitative reflections indicates that the PD program not only succeeded in enhancing teachers’ knowledge and confidence across the core domains of STEAM, data science, and social justice education, but also reshaped their pedagogical perspectives in ways that are likely to influence their classroom practice. The structure of the PD—grounded in upfront participant profiling, responsive to teacher feedback, and rich in collaborative inquiry—demonstrates a potentially scalable model for designing professional development that is both contextually grounded and future-oriented.

DISCUSSION AND CONCLUSION

The preliminary findings of this pilot implementation underscore the potential of targeted PD in equipping teachers to integrate data science meaningfully into interdisciplinary STEAM education with a focus on civic engagement. The results show that foundational training in STEAM, supported by hands-on experience with digital tools and ethical reflection, can significantly enhance teacher confidence and conceptual clarity. Teachers progressed from limited familiarity with data science and STEAM to developing complex, cross-curricular scenarios grounded in real-world data and ethical inquiry. This shift highlights the importance of embedding PD within authentic and socially relevant educational contexts (Desimone, 2009; Darling-Hammond et al., 2017).

Several challenges and enablers emerged throughout the implementation. Initial unfamiliarity with interdisciplinary teaching and STEAM principles posed obstacles, particularly for teachers with traditionally siloed subject expertise. However, the high technological readiness of participants, coupled with structured collaboration and sustained support, enabled them to overcome these barriers. The modular structure of the PD, along with its emphasis on inquiry-based learning, played a crucial role in fostering teacher agency and cross-disciplinary dialogue. Nonetheless, feedback from participants points to a need for extended time to practice using tools like CODAP and for deeper peer collaboration prior to classroom implementation. These insights suggest that future iterations should prioritize time for tool exploration and co-planning (Kennedy, 2016; Borko, 2004).

This study is not without limitations. As an early-stage pilot, the small sample size and relatively short duration of the professional development limit the generalizability of the findings. Although data were collected from both teachers and students, this paper reports only on data gathered from teachers, focusing on their perspectives regarding the effectiveness of the DataScEd4CiEn approach. Additionally, systemic constraints—such as limited time for collaborative planning and the challenge of aligning innovative interdisciplinary projects with existing curricular structures—posed practical difficulties. These constraints underscore the need for institutional support and policy alignment to sustain long-term, interdisciplinary teacher learning. Despite the limitations, the initial outcomes suggest a promising framework for empowering educators to engage students in critical, data-driven inquiry with a social justice lens.

Looking forward, the findings from this pilot are guiding the iterative refinement of the PD model. Greater attention will be paid to balancing technological training with pedagogical depth, providing more scaffolding for the integration of civic themes, and embedding assessment strategies suited to interdisciplinary outcomes. Further research is planned to explore the longitudinal impact of this PD approach, its scalability across different educational contexts, and the effects on student outcomes in areas such as data literacy, ethical reasoning, and civic awareness.

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