

The DataScEd4CiEn Framework

Designing Meaningful Data Science Learning for Civic Engagement and Social Justice

A Guide for Teachers, Teacher Educators and Curriculum Designers



DataScEd4CiEn: Data Science Education in STEAM for Civic Engagement and Social Justice from the Early Years



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Section 1: Why Data Science Matters

Every day, young people encounter data. Whether checking the weather forecast, interpreting election results, following sports statistics, scrolling through social media, or interacting with artificial intelligence (AI), they are constantly surrounded by information generated from data. Increasingly, personal, scientific, economic, and political decisions are informed by data, making the ability to reason with data an essential competency for all citizens.

Traditionally, schools have introduced students to data through topics such as graphs, averages, probability, and statistics. While these remain important, they are no longer sufficient on their own. Today's learners need opportunities to investigate authentic questions using real data, evaluate evidence critically, recognise uncertainty, and communicate evidence-based conclusions. In doing so, they develop the knowledge, skills, and habits of mind associated with data science.

These developments have important implications for education. Around the world, curriculum reforms increasingly recognise the importance of preparing young people to participate in a data-rich society. At the same time, integrated STEM (and STEAM) education has become a major educational priority, encouraging learners to investigate authentic problems through interdisciplinary inquiry. Bringing these ambitions together in classroom practice, however, remains challenging. Teachers need approaches that do more than combine disciplines; they need learning experiences that help students draw on different forms of knowledge to explore meaningful real-world issues. Data science provides one such opportunity.

The rapid emergence of AI makes these capabilities even more important. Because modern AI systems are fundamentally data-driven, understanding how data are collected, interpreted, and used has become an essential aspect of AI literacy. Learners therefore need to do more than use AI tools—they need to question evidence, recognise uncertainty and bias, and appreciate the ethical and societal implications of data-driven decisions.

The DataScEd4CiEn project was established in response to these educational opportunities and challenges. It recognises data science as a powerful context for integrating knowledge and practices from across STEM (and STEAM) while investigating authentic issues that matter within learners' own communities and beyond. In doing so, learners develop not only disciplinary understanding but also the critical, ethical, and civic capacities needed to participate thoughtfully in an increasingly data-rich world.

Section 2: The DataScEd4CiEn Framework

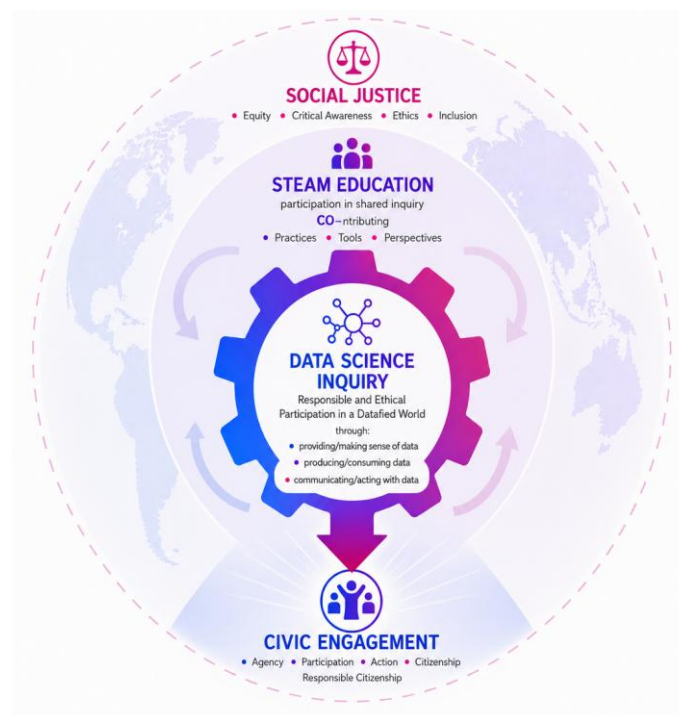
The DataScEd4CiEn Framework was developed to support teachers, teacher educators, curriculum developers, and researchers in designing meaningful data science learning experiences. Rather than viewing data science simply as a collection of technical skills, the framework positions it as a process of interdisciplinary inquiry in which learners investigate authentic problems using data. Meaningful data science learning involves asking worthwhile

questions, working with evidence, drawing on knowledge from multiple disciplines, considering ethical and societal implications, and communicating findings that can inform understanding and action.

The framework emerged through an iterative and collaborative process involving researchers and teacher educators from across Europe. It brings together insights from research in data science education, STEM education, statistics education, mathematics education, computational thinking, civic engagement, and social justice education into a coherent model for teaching and learning. Throughout the project, the framework was refined through discussion, classroom implementation, and reflection, ensuring that it remained both theoretically robust and practically useful.

Rather than prescribing lessons or activities, the framework serves as a design tool. It supports educators in planning, implementing, and reflecting on meaningful data science learning across a wide range of educational settings. The four interconnected elements shown in Figure 2.1 provide a shared language for designing investigations that are intellectually rigorous, educationally meaningful, and socially relevant.

Figure 2.1. *The DataScEd4CiEn Conceptual Framework*



Section 3: Understanding the Framework

The DataScEd4CiEn Framework presents a vision of data science learning in which authentic inquiry, interdisciplinary thinking, social justice, and civic engagement come together through meaningful investigations with data. Rather than representing a sequence of teaching steps, the framework illustrates the interconnected elements that characterise high-quality data science learning.

At the centre of the framework is data science, understood as a process of inquiry through which learners investigate authentic questions, work with evidence, construct explanations, and communicate findings that can inform understanding and action. Surrounding this process are four complementary elements - *Data Science Practices*, *Integrated STEAM Education*, *Social Justice*, and *Civic Engagement* - that together shape the design of meaningful learning experiences.

These elements are intended to work together rather than in isolation. Different investigations may place greater emphasis on some elements than others, but it is their interaction that makes data science learning intellectually rigorous, educationally meaningful, and socially relevant. The following sections briefly introduce each element of the framework.

3.1 Data Science Practices: What do we mean?

Data science practices are the knowledge, skills, and ways of thinking that enable learners to work effectively with data. They include asking meaningful questions, collecting or accessing data, preparing and exploring datasets, identifying patterns, interpreting evidence, communicating findings, and reflecting on the strengths and limitations of their conclusions.

Importantly, these practices extend beyond technical skills. Learners are encouraged to consider where data come from, how they were collected, whose perspectives are represented, and how ethical considerations influence both data collection and interpretation. As AI becomes increasingly embedded within society, these practices also include developing the confidence to question AI-generated outputs rather than accepting them uncritically.

Rather than teaching these practices in isolation, the framework encourages educators to embed them within authentic investigations where they develop naturally through meaningful inquiry.

3.2 Integrated STEAM Education: What do we mean?

Authentic problems rarely belong to a single discipline. Questions relating to sustainability, health, climate, or social issues require knowledge and perspectives from across STEM and often the arts and humanities.

The framework positions data science as a natural context for integrated STEAM learning. Rather than combining subjects for their own sake, it encourages educators to draw upon the distinctive contributions of each discipline. Science provides knowledge of the natural or social world, mathematics and statistics support reasoning with data, technology and computing enable

data collection and analysis, engineering contributes design thinking, while the arts and humanities enrich communication, creativity, ethical reflection, and human-centred perspectives.

In this way, learners experience how different disciplines work together to investigate complex real-world problems.

3.3 Social Justice: What do we mean?

The framework recognises that data are never entirely neutral. Decisions about what data are collected, whose experiences are represented, and how findings are interpreted all influence the stories that data tell.

The social justice dimension encourages learners to examine issues of equity, representation, fairness, and inclusion through data. By asking critical questions about the evidence they encounter, learners develop a deeper appreciation of both the power and the limitations of data in understanding society and informing decisions.

This perspective encourages educators to select contexts that are meaningful to learners while fostering thoughtful and ethical engagement with data.

3.4 Civic Engagement: What do we mean?

The DataScEd4CiEn Framework emphasises that data science extends beyond analysing information; it also provides opportunities for informed participation in society.

Authentic investigations encourage learners to communicate findings, share evidence with others, make recommendations, and consider how data can contribute to positive change within their schools or communities. Civic engagement does not imply advocating predetermined positions; rather, it encourages learners to use evidence responsibly, consider multiple perspectives, and recognise the role that data can play in informed decision-making.

By connecting classroom investigations with issues that matter beyond school, learners begin to see data science as a powerful means of understanding—and contributing to—the world around them.

Section 4: Using the Framework

The DataScEd4CiEn Framework is intended as a design framework rather than a prescribed teaching model. It does not specify a sequence of lessons or a single approach to teaching data science. Instead, it provides a shared language for designing, implementing, and reflecting on meaningful data science learning.

The framework is flexible and can be used in a variety of educational contexts. Different investigations may emphasise different elements of the framework depending on learners' ages,

curricular goals, available data, and local contexts. What remains consistent is the commitment to authentic inquiry, interdisciplinary learning, critical engagement with data, and meaningful connections to issues that matter.

The framework can support a range of educational purposes.

Teachers -The framework can be used to design investigations that engage learners with authentic questions, real data, and meaningful contexts. It encourages teachers to create learning experiences that integrate disciplinary knowledge while developing data science practices, critical thinking, and civic awareness.

Teacher Educators - The framework provides a shared language for preparing future teachers to design and facilitate data-rich learning experiences. It can support programme design, professional learning, and reflection on classroom practice.

Curriculum Developers - The framework offers a way of considering how data science can be integrated within existing curricula while maintaining meaningful connections between disciplines and ensuring learning remains socially relevant.

Researchers - The framework can also serve as a conceptual lens for analysing the design and implementation of data science learning environments, supporting research into interdisciplinary learning, data science practices, and civic engagement.

Ultimately, the framework is intended to inspire rather than prescribe. It encourages educators to adapt its principles to their own contexts while keeping learners engaged in authentic investigations that help them understand (and where possible, improve) the world around them.

Section 4. Looking Ahead

As societies become increasingly shaped by data and artificial intelligence, education has an important role to play in helping young people become thoughtful, critical, and informed users of data. The DataScEd4CiEn Framework provides one vision for how this can be achieved by bringing together data science, integrated STEAM education, social justice, and civic engagement within meaningful learning experiences.

While developed through the DataScEd4CiEn project, the framework is intended to be adapted and extended across a wide range of educational contexts. We hope it will support educators, teacher educators, curriculum developers, and researchers in designing learning experiences that prepare young people not only to understand a data-rich world, but also to participate responsibly in shaping it.