Constellations: Online STEM Teacher Education Journal

Volume 1 *Inaugural Issue* Article 3

2024

Melding Mindsets: Isolated Content, Same Destination, Hidden Opportunity

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The authors, drawing from their background as special educators, bring a unique perspective to working across both mathematics and science, an opportunity not commonly available to many teachers who are specific content experts. Their ability to engage with multiple content areas has revealed numerous underutilized opportunities with the potential for overlap and integration of mathematics and science content through cross-curricular instruction. The following article highlights the connections between mathematics and science standards, reviews cross-curriculum instruction (CCI) and its different forms of implementation, and concludes with practical recommendations for getting started.

Connections Across Standards

Mathematics and science are often considered distinct disciplines, each operating within its own principles and methodologies. However, the content shares an interconnection evident through content standards such as the National Council of Teachers of Mathematics (NCTM) Process Standards (Ferrini-Mundy, 2000) and Next Generation Science Standards (NGSS) Science and Engineering Practices (National Research Council, 2012). These frameworks not only bind the contents together but also underscore the pivotal role they play in molding informed citizens (Chowhury et al., 2020; Maass et al., 2019). The collaboration of mathematics and science opens up many opportunities for learners, extending beyond the classroom even for those not venturing into Science, Technology, Engineering, and Mathematics (STEM) fields. Through CCI, students can explore disciplines in tandem, furthering their understanding and supporting informed citizenship.

The NCTM Process Standards and NGSS Science and Engineering Practices aim to enhance students' understanding and application of fundamental concepts in mathematics and

science. For example, the NCTM Process Standard of "Problem-Solving" aligns with the NGSS Science and Engineering Practice of "Planning and Carrying Out Investigations" as both encourage students to investigate and explore solutions. For example, students apply linear and exponential growth models to predict bacterial population changes while testing these predictions through experiments on bacterial growth under varying conditions. Similarly, the NCTM's "Representation" standard, which emphasizes communicating mathematical ideas, aligns with NGSS's scientific and engineering practice of "using mathematics and computational thinking," promoting the use of different representations of mathematics while using models. Students use graphs to represent historical climate data in math class, while in science class, they apply these representations to computational models predicting future climate trends. These alignments facilitate an integrated approach, aiding students in recognizing and applying overarching themes and methodologies across both disciplines. Review the resource Melding Mindsets: Bridging Mathematical Standards and Scientific Practices Handout for an overview of the interconnection across all standards and practices.

Importance of Mathematics and Science

In a world increasingly steered by innovations and the need for scientific and mathematical literacy as citizens, an educated population in mathematics and science allows for problem-solving skills, critical thinking, and making informed choices (Halpern, 2014). The importance of mathematics and science education transcends the classrooms and the realms of STEM fields. Even for those not venturing into STEM careers, a foundational understanding of mathematics and science is pivotal in nurturing informed, competent, and adaptable citizens (Halpern, 2014). In the following sections, we will delve into the essence of CCI, explore how CCI embodies the principles of Universal Design for Learning (UDL), and offer practical

recommendations for kick-starting your journey with CCI in the classroom, paving the way for a more integrated and inclusive learning experience.

What is Cross-Curricular Instruction?

Cross-curricular instruction, often referred to as interdisciplinary or integrated teaching, is an instructional approach that combines content and skills from multiple subject areas into a single thematic unit or lesson. Instead of teaching subjects in isolation, educators integrate subjects to create a more holistic, contextual, and relevant learning experience for students (Berasategi et al., 2020). This method encourages students to connect with different disciplines, fostering a deeper understanding and appreciation of the content. For teachers, CCI offers the opportunity to collaborate with colleagues from different subject areas, share expertise, and design innovative lessons that engage students in meaningful and authentic tasks. By breaking down the traditional silos of subject-specific teaching, educators can better prepare students for the interconnected world they will encounter outside the classroom (Chau et al., 2021; Nikitina & Mansilla, 2003).

CCI: Embodying Universal Design for Learning

Universal Design for Learning is an educational framework catering to the diverse needs of every learner by providing multiple means of representation, engagement, and expression. A cross-curricular approach reflects UDL's multiple means of representation by allowing students to engage with concepts through various disciplinary lenses, catering to different learning styles, and making connections that enrich understanding across subjects (Gauvreau et al., 2019). Furthermore, by facilitating a multifaceted exploration of concepts, students can perceive and interpret information from various disciplinary lenses (Berasategi, 2020). For instance, integrating mathematics and science allows learners to visualize scientific phenomena through

mathematical models, diagrams, and graphs. Moreover, CCI fosters an inclusive classroom environment where each learner, regardless of their primary learning mode, can engage with and benefit from a well-rounded educational experience (Nikitina & Mansilla, 2003).

An Integrated Continuum

Without prior experience or exposure, CCI may seem overwhelming to initiate. Focusing on one content area may seem hard enough without considering an additional subject area. However, CCI can take many forms to meet the unique needs of your class, colleagues, schedules, and comfort with CCI. Applebee and Flihan (2007) break down the CCI continuum into four levels from the least to the most amount of integration, described below. See Figure 1 for examples across CCI levels.

- **Predisciplinary:** Subjects are taught independently, each subject isolated from the others without intentional connections.
- **Disciplinary Correlated:** Subjects remain distinct but are taught in a sequence or parallel manner that allows for thematic connections.
- **Shared:** Different disciplines are integrated around a common theme or project, with each contributing to a unified learning objective.
- **Reconstructed:** The curriculum fully integrates multiple disciplines into a comprehensive study centered around complex, real-world problems.

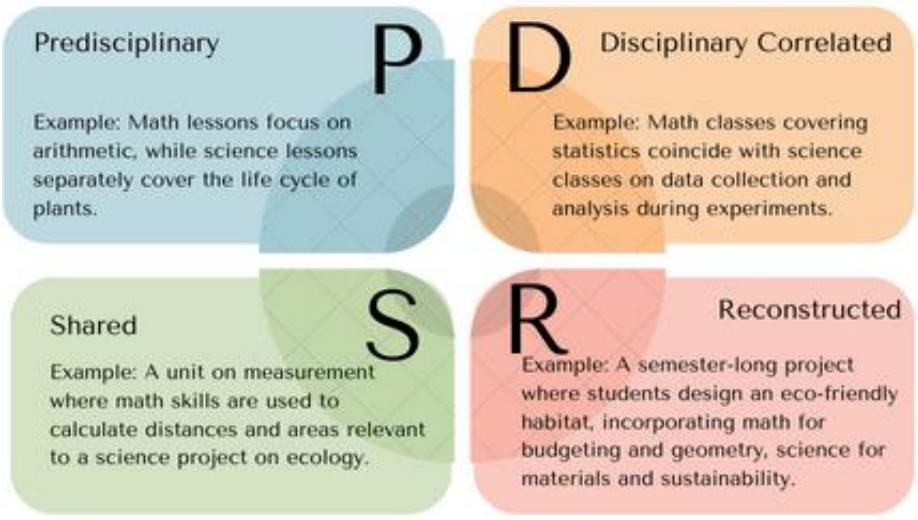

Figure 1: Examples of different levels of Cross Curriculum Instruction

Recommendations for Getting Started

Embracing a cross-curricular approach can significantly enrich the learning environment, resonate with the principles of UDL, and shape informed citizens. Timmerman (2019) provides easy-to-implement recommendations to guide your initial steps for integration:

1. Start Small and Be Flexible:
    - Start with a small-scale integration, focusing on one or two areas where mathematics and science naturally intersect. Flexibility is key; be open to adjusting your approach based on the experiences and feedback.
2. Share Curriculum Maps:
    - Sharing curriculum maps with colleagues can foster a collaborative environment, allowing for the identification of potential cross-curricular connections.
3. Seek Assistance and Utilize Resources:
    - If you encounter challenges or need guidance, do not hesitate to ask for help, as many districts and schools have resources for support (e.g., STEM coaches or content leads).

4. Engage in Professional Development:
    - Consider participating in professional development opportunities focused on CCI and UDL. This will not only enhance your skills but also expand your network of like-minded educators.
5. Reflect and Adjust:
    - Reflect on the effectiveness of your cross-curricular endeavors, gather student feedback, and be prepared to make necessary adjustments to improve the learning experience.

Conclusion

Mathematics and science, often taught separately, are interconnected through content and aligned with content frameworks like the NCTM Process Standards and NGSS Science and Engineering Practices. The relationship between mathematics and science content broadens learning opportunities beyond the classroom. In today's world, problem-solving, critical thinking, and the need for discipline-specific content knowledge are essential for being an informed citizen. The cross-curricular approach, aligned with UDL, allows for exploring concepts and fostering an inclusive and engaging learning environment. For educators, starting small, sharing curriculum outlines, seeking guidance, engaging in professional development, and maintaining flexibility are crucial steps toward successful integration.

We invite educators, just like ourselves, to explore the interconnectedness of mathematics and science, promoting a holistic teaching and learning approach and preparing students to navigate the complexities of the modern world.

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Melding Mindsets: Bridging Mathematical Standards and Scientific Practices

NCTM Process Standards	NGSS Science & Engineering Practices	Shared Classroom Content	Specific Classroom Example
Problem-Solving	1) Asking Questions and Defining Problems 2) Planning and Carrying Out Investigations 3) Constructing Explanations and Designing Solutions 4) Using mathematics and computational thinking	Investigative and Exploratory Learning	Students calculate growth rates and predict future growth patterns of plants while experimenting with plant growth and using mathematical predictions.
Reasoning and Proof	1) Engaging in Argument from Evidence 2) Analyzing and Interpreting Data 3) Obtaining, Evaluating, and Communicating Information	Critical Thinking and Data Analysis	Students use statistical methods to analyze data from an experiment conducted in science class about forces and motion.
Communication	1) Obtaining, Evaluating, and Communicating Information 2) Engaging in Argument from Evidence	Effective Communication and Data Presentation	Students analyze environmental data to create graphs and reports while students present findings on local environmental issues, using mathematical data analysis to support their arguments.
Connections	1) Using Mathematics and Computational Thinking 2) Developing and Using Models	Integrating Math and Science Concepts	Students learn about geometric sequences and apply them to model population growth while students study population dynamics in ecosystems, using mathematical models to predict future changes.
Representation	1) Developing and Using Models 2) Using Mathematics and Computational Thinking	Visualization and Modeling	Students learn about scale and proportion while creating models of the solar system to understand planetary distances and sizes.

Note. The table represents a synthesis of concepts from the National Council of Teachers of Mathematics (NCTM) Process Standards (Ferrini-Mundy, 2000) and the Next Generation Science Standards (NGSS) Science & Engineering Practices (National Research Council, 2012)