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Integrating STEM+C into Elementary Science Teacher Education: Addressing Challenges with Engineering Design and Computational Thinking

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Introduction

Elementary teachers today face a persistent challenge: there is an increasing amount of content and skills to teach to prepare their students for the knowledge they will need later in life, but there is limited instructional time. Some of the these additions include integrating concepts from engineering and computational thinking (CT) into elementary classrooms, and usually as a part of science instruction, as evidenced by the inclusion of engineering and CT in the Next Generation Science Standards (NGSS) and CT is also often embedded into (CS) standards that have been adopted in many states (NGSS Lead States, 2013, Tissenbaum & Ottenbreit-Leftwich, 2020). While these additions reflect an important effort to better prepare students for future learning and work in STEM fields, they also place new demands on elementary teachers, as many have limited background and experience in these emerging areas (Banilower et al., 2018; Ottenbreit-Leftwich et al., 2021). Additionally, science instruction in elementary classrooms is already constrained by limited instructional time and competing curricular priorities in reading and mathematics.

One promising response to this challenge is to use an "integrated STEM" approach, which emphasizes integrating science, technology, engineering, and mathematics, as well as a broader emphasis on interconnected knowledge, interdisciplinary problem-solving, student-centered pedagogies, and real-world relevance (Moore et al., forthcoming). Rather than teaching isolated subjects, integrated STEM instruction engages elementary students in authentic, interdisciplinary learning experiences that connect academic content to real-world problems and phenomena, increasing engagement and motivation and supporting deeper learning (Moore et al., 2020).

Both engineering design and CT can facilitate learning within and across STEM disciplines at the elementary level (Tank et al., 2018). When thinking about embedding these into elementary science activities, the Framework for STEM Integration in the Classroom (Moore et al., 2014) suggests the following key design principles: authentic and engaging contexts, iterative design with opportunities for failure and redesign, meaningful integration of science and mathematics content, student-centered learning, and explicit connections across disciplines through an engineering challenge. They are not presented as additional or isolated topics to be taught, but rather as a continuous thread throughout instruction.

CT, which can be defined as "a problem-solving process that includes formulating problems, logically organizing data, representing data through abstraction, automating solutions, reflecting on the efficiencies of possible solutions, and generalizing and transferring this process to a variety of problems" (ISTE & CSTA, 2011, p. 1). It has been suggested as a foundational skill that all students should learn (Wing, 2006), especially with younger students (Su &Yang, 2023). CT has also been found to be an important foundation for STEM learning (Weintrop et al., 2016). It supports STEM learning by offering a new lens for approaching problems, analyzing systems, and deepening content understanding (Rich et al., 2019). The addition of CT into STEM instruction, or STEM+C, can be framed in multiple ways when thinking about the integration of CT into elementary classrooms, including CT as a problem solving approach that highlights overlapping practices and skills with other STEM disciplines (Shute et al., 2017), as a support for deeper content learning (Lee et al., 2020; Rich et al., 2019), or as a context for engaging in and facilitating STEM learning through the interdisciplinary nature of CT (Li et al., 2020). Integrating CT and STEM has been shown to benefit learning in both CT and STEM (Weintrop et al., 2016) and to provide students with opportunities to practice real-world skills and practices that parallel the work of STEM professionals (Lee et al., 2020).

Within this framing, STEM and STEM+C integration are increasingly viewed not as add-ons to existing instruction but as a way to meaningfully organize and connect learning across disciplines. Furthermore, the use of STEM+C integration in elementary science should not be understood as a replacement for disciplinary science instruction. Rather, it can serve as a complementary approach that strengthens science learning by connecting it to mathematics, technology, engineering, and computational thinking. When thoughtfully designed, STEM integration experiences can make science more relevant and meaningful for young learners while also supporting the development of curiosity, creativity, and critical thinking skills. This is particularly important in elementary contexts, where instructional time is limited but opportunities for foundational STEM learning are essential.

Engineering Design and Computational Thinking as Facilitators of STEM Integration

When considering STEM+C integration in elementary classrooms, engineering design and CT serve as powerful facilitators in connecting concepts and practices across disciplines. Engineering design provides students with authentic, problem-based contexts in which they apply scientific knowledge, mathematical reasoning, and technological tools to develop and improve solutions, while CT supports students in breaking down complex problems, recognizing patterns, and developing algorithms (Caeli & Yadav, 2020; Moore et. al., 2014). These represent distinct yet overlapping disciplinary practices and contexts relevant to both fields. Together, engineering design and CT promote inquiry, creativity, and problem-solving while providing a common framework that facilitates learning and connections among science, technology, engineering, and mathematics. By engaging students in decomposing, designing, testing, and refining solutions to real-world challenges, these approaches help move integrated instruction beyond isolated discipline-specific learning toward meaningful interdisciplinary experiences.

Here, I present an example for STEM+C integration that positions engineering and CT as facilitators of this integration for use in elementary classrooms and teacher education settings.

This model also reflects approaches that I use in my own preservice teacher education courses to better prepare future teachers for current realities within their future elementary classrooms.

Engineering Design and CT within an Elementary School-Based Teaching Experience

On a typical morning during the elementary school teaching experience associated with the *Toying with Technology (TWT)* course, visitors moving between classrooms would observe a variety of learning activities that, at first glance, might appear quite different from one another. In one corner of a classroom, a group of elementary students carefully place a Dash robot by Wonder Workshop on a foam surface and watch as it travels forward. Students record the distance traveled before moving to a thick carpet, a regular carpet, and a laminated mat. At each station, they conduct three trials and document their observations and measurements on a worksheet. After completing each station, the preservice teachers (PSTs) ask the elementary students to use their data and observations to make claims about how Dash moves on different surfaces.

Across the room, another small group has just finished listening to *Seeds Move!* by Robin Page. Guided by a preservice teacher (PST), students discuss how animals transport seeds to new locations and how this helps plants spread. Working in pairs, they then use ScratchJr (https://www.scratchjr.org/) to create a story about how animals help to move seeds. The elementary students sequence actions, debug their programs, and revise their representations as their digital stories become tools for communicating scientific ideas while simultaneously engaging in CT practices. Meanwhile, in a partner classroom, PSTs are facilitating an engineering design challenge inspired by *The Three Little Pigs*. Students investigate the properties of straw, sticks, and bricks before designing and constructing model houses intended to withstand simulated wind. As designs are tested, students observe failures, propose improvements, and redesign their structures. Discussions center on material properties, evidence-based decision making, and the iterative nature of design.

Although these lessons focus on different disciplinary content—physical science, life science, and engineering—they share a common emphasis on integrated CT and engineering design practices. Each lesson was planned and taught by PSTs enrolled in the TWT course, an elementary STEM methods experience designed to help future teachers explore how learning technologies can support creative, innovative, and hands-on learning opportunities. Within this course, engineering design and CT serve as organizing frameworks through which technology integration occurs across STEM-related educational contexts.

The TWT course intentionally begins by helping PSTs develop their own understanding of CT and engineering design before asking them to teach these ideas in elementary classrooms. During university-based coursework, PSTs engage in a variety of elementary-focused activities that allow them to experience CT and engineering design challenges firsthand. For example, they participate in an engineering design and CT Lego challenge where they use Lego programming kits to design a rover that can identify and collect a specimen before returning to base. Through these experiences, they learn to identify the underlying practices embedded in activities, examine connections among engineering, CT, and STEM, and reflect on how different learning technologies can support student learning. PSTs then work with a partner to design and implement one CT lesson and one engineering design lesson for students in a local elementary school, like those lessons described above. Elementary classroom experiences provide opportunities to enact ideas discussed in the university setting while adapting instruction to authentic classroom contexts. In the examples above, PSTs were responsible for designing the learning activities, facilitating student engagement, collecting evidence of learning, and reflecting on the ways CT and engineering design served as facilitators of STEM learning during instruction.

The final weeks of the course are devoted to helping PSTs synthesize these experiences and recognize the broad applicability of CT and engineering design across disciplines. Through structured reflection and analysis of their classroom teaching experiences, PSTs examine how CT and design practices emerged within science, literacy, technology, and engineering contexts. This process helps future teachers move beyond viewing CT as synonymous with programming and instead recognize its potential as a powerful framework for supporting inquiry, problem solving, communication, and learning throughout the elementary curriculum.

Implications for Elementary Science Teacher Education

The use of engineering design and CT as facilitators of STEM integration has direct implications for elementary science teacher education. In teacher education contexts, such as science methods courses, PSTs can engage with engineering design and CT as frameworks for thinking about interdisciplinary teaching across STEM subjects. For example, PSTs might participate in a STEM integration lesson or unit within a methods course and then reflect on how engineering design and/or CT supports science learning in that integrated experience. One example used in my elementary science methods course is the *Designing Hamster Habitats* Unit from the PictureSTEM curriculum (www.pictureSTEM.org), which leads students through a series of STEM+C lessons to solve the engineering design challenge of creating a new hamster habitat for Perri's Pet Palace. PSTs can then be guided to design their own integrated STEM lessons that leverage engineering design or CT as an organizing structure. Another option is similar to the example described above, in which PSTs are given opportunities to design and/or teach engineering design and CT-integrated STEM lessons to students in elementary classrooms. Thus, allowing them to experience firsthand how engineering and CT can be embedded within instruction. These experiences provide critical opportunities for practice, application, and reflection, which are key components for developing confidence and competence in STEM integration.

Several takeaways emerge for teacher educators seeking to implement STEM Integration lessons centered on engineering design and CT. First, engineering design and CT should be positioned not as additional content to be taught separately, but as pedagogical frameworks that help organize interdisciplinary learning around authentic problems and phenomena. Explicitly modeling how engineering design and CT can support learning in science and STEM is important for helping teachers to recognize the value in adopting an integrated approach. Second, providing opportunities for teachers to experience STEM integration as learners before expecting them to design and teach their own lessons is important, as integration demands teacher expertise in multiple disciplines and a clear understanding of the overlaps. This progression from participant to lesson designer to implementor can help build both conceptual understanding and self-efficacy. Third, access to high-quality curricular resources and examples is critical, as many elementary teachers have limited background and experience with engineering and CT, especially within the context of STEM integration. Finally, structured reflection on both successes and challenges is essential to helping teachers learn to create and implement integrated STEM+C experiences in elementary classrooms. Ultimately, elementary teacher education must move beyond merely introducing discrete STEM concepts and teaching methods by also providing future teachers with flexible frameworks for integration. Engineering design and CT provide two such frameworks that can help elementary teachers navigate the constraints of elementary classrooms while still supporting meaningful STEM learning.

Benefits of an Integrated STEM+C Approach

Integrated STEM+C instruction, particularly when anchored by engineering design and CT, offers numerous benefits for early elementary learners and teachers. By connecting science, technology, engineering, mathematics, and CT within meaningful learning experiences, STEM+C approaches help maximize limited instructional time by allowing multiple content areas to be addressed simultaneously, often alongside literacy and mathematics goals. The interdisciplinary nature of STEM+C learning increases relevance and student engagement by situating learning within authentic, real-world problems that encourage curiosity and purposeful inquiry. These experiences also support the development of essential 21st-century competencies, including creativity, collaboration, critical thinking, and problem-solving, while strengthening foundational science and mathematics understanding. Additionally, STEM+C approaches that highlight engineering design and CT are consistent with NGSS and CS standards that are being emphasized across the country, with a goal of preparing students with essential scientific and engineering practices from an early age. Collectively, these benefits position STEM+C instruction as a powerful option for delivering engaging, relevant, and integrated elementary science.

Conclusion

Implementing a STEM+C integrated approach offers a practical and theoretically grounded solution to current challenges facing elementary science. By using engineering design and CT as organizing frameworks, teachers can create interdisciplinary learning experiences that are coherent, engaging, and feasible for elementary classrooms. Interdisciplinary, real-world problem-solving connects content areas and makes learning more meaningful, especially for younger students. Utilizing this integrated approach to instruction keeps science learning central while also connecting it to mathematics, technology, engineering, and CT. It provides a structure that supports implementation when time is limited for additional subjects or content, reduces curricular silos, and enhances student engagement through authentic problem-solving. Most importantly, STEM+C integration offers a pathway for sustaining science instruction in elementary classrooms where time and resources are limited, while also expanding access to meaningful STEM learning experiences for all students.

References

Banilower, E. R., Smith, P. S., Malzahn, K. M., Plumley, C. L., Gordon, E. M., & Hayes, M. L. (2018). *Report of the 2018 National Survey of Science and Mathematics Education.* Chapel Hill, NC: Horizon Research, Inc.

Caeli, E. N., & Yadav, A. (2020). Unplugged approaches to computational thinking: A historical perspective. *TechTrends*, *64*(1), 29–36. https://doi.org/10.1007/s11528-019-00410-5

ISTE, & CSTA. (2011). Operational definition of computational thinking for K–12 education. *National Science Foundation*. https://cdn.iste.org/www-root/Computational_Thinking_Operational_Definition_ISTE.pdf

Lee, I., Grover, S., Fred Martin, Pillai, S., & Malyn-Smith, J. (2020). Computational thinking from a disciplinary perspective: Integrating computational thinking in K-12 science, technology, engineering, and mathematics education. Journal of Science Education and Technology, 29(1), 1–8. https://doi.org/10.1007/s10956-019-09803-w

Li, Y ., Schoenfeld, A. H., diSessa, A. A., Graesser, A. C., Benson, L. C., English, L. D., & Duschl, R. A. (2020). On computational thinking and STEM education. Journal for STEM Education Research, 3(2), 147–166. https://doi.org/10.1007/s41979-020-00044-w

Moore, T. J., Johnston, A. C., & Glancy, A. W. (2020). STEM integration: A synthesis of conceptual frameworks and definitions. In C. C. Johnson, M. J. Mohr-Schroeder, T. J. Moore, & L. D. English (Eds.), Handbook of Research on STEM Education (1st ed., pp. 3–16). Routledge.

Moore, T. J., Stohlmann, M. S., Wang, H.-H., Tank, K. M., Glancy, A. W., & Roehrig, G. H. (2014). Implementation and integration of engineering in K-12 STEM education. In Ş. Purzer, J. Strobel, & M. Cardella (Eds.), Engineering in precollege settings: Research into practice (pp. 35–60). Purdue University Press.

Moore, T. J., Tank, K. M., van Driel, J. H., Wang, H.-H., Berry, A., & Abanoz, T. (Forthcoming 2026). STEM integration revisited: Evolving frameworks and definitions. In C. C. Johnson, M. Mohr-Schroeder, T. J. Moore, L. D. English, & C. Jackson (Eds.), *Handbook for Research in STEM Education* (Volume 2). Routledge.

NGSS Lead States. (2013). Next Generation Science Standards: For States, By States. Washington, DC: The National Academies Press. Retrieved from http://www.nextgenscience.org/

Ottenbreit-Leftwich, A., Yadav, A., & Mouza, C. (2021). Preparing the next generation of teachers: Revamping teacher education for the 21st cen-tury. In A. Yadav & U. Berthelsen (Eds.), *Computational thinking in edu-cation: A pedagogical perspective* (pp. 151–171). Routledge. https://doi. org/10.4324/9781003102991

Rich, K. M., Yadav, A., & Schwarz, C. V. (2019). Computational thinking, mathematics, and science: Elementary teachers' perspectives on integration. Journal of Technology and Teacher Education, 27(2), 165–205. https://doi.org/10.70725/303733vqleui

Shute, V. J., Sun, C., & Asbell-Clarke, J. (2017). Demystifying computational thinking. Educational Research Review, 22, 142–158. https://doi.org/10.1016/j.edurev.2017.09.003

Tank, K. M., Moore, T. J., Dorie, B. L., Gajdzik, E., Terri Sanger, M., Rynearson, A. M., & Mann, E. F.(2018). Engineering in early elementary classrooms through the integration of high-quality literature, design, and STEM+C content. In L. English & T. Moore (Eds.), Early engineering learning (pp. 175–201). Springer Singapore. https://doi.org/10.1007/978-981-10-8621-2_9

Tank, K.M., Ottenbreit-Leftwich, A., Moore, T.J., Yang, S [2]., Wafula, Z. [2], Kim, J. [2], Fagundes, B., & Chu, L. [2] (2024). Investigating Sequencing as a Means to Computational Thinking in Young Children. *International Journal of Computer Science Education in Schools*. 6(3), 67-77. https://doi.org/10.21585/ijcses.v6i3.192

Tissenbaum, M., & Ottenbreit-Leftwich, A. (2020). A vision of K-12 computer science education for 2030. *Communications of the ACM, 63*(5), 42-44. https://doi.org/10.1145/3386910

Weintrop, D., Beheshti, E., Horn, M., Orton, K., Jona, K., Trouille, L., & Wilensky, U. (2016). Defining computational thinking for mathematics and science classrooms. Journal of Science Education and Technology, 25(1), 127–147. https://doi.org/10.1007/s10956-015-9581-5

