Leading with Technology: Enhancing Mathematics for All Students

A Position Statement from NCSM: Leading with Technology

Our Position

NCSM, Leadership in Mathematics Education believes that in order to develop all students' mathematics proficiency, mathematics leaders must purposefully integrate appropriate technologies in the classroom to strengthen teaching practices, enhance the curriculum, attend to students' diverse learning needs and better assess student learning. Despite the advancements in educational technology, there exists a gap in integrating and leveraging technologies to develop and assess high quality learning experiences. Likewise, the ways in which mathematics teacher leaders can support and improve the work of teachers has drastically changed with the continued advancement of technology like educational Artificial Intelligence (AI) tools, adaptive online games for learning and virtual manipulatives. Research indicates that purposeful technology integration can enhance engagement when appropriately balanced with sound pedagogy and intentional planning (Clark & Mayer, 2016; Hwang et al., 2020). Likewise, when the technology helps accentuate key mathematical concepts, skills and ways of thinking, it can also enable personalized learning (Barab et al., 2019), cultivate essential skills like higher-order thinking and problem solving (Puentedura, 2014) and promote inclusivity by providing access to learning that may not otherwise be available to learners with unique needs (Santamaría et al., 2022). As mathematics teacher leaders, it is incumbent upon us to champion the purposeful integration of technology, recognizing its potential to reimagine mathematics education and help teachers empower students to thrive in an ever-evolving digital landscape.

Recognizing the Potential of Technologies

In the dynamic landscape of mathematics education, the integration of technology has become paramount in fostering meaningful and effective learning experiences and can serve as a powerful catalyst for transforming traditional pedagogical approaches. The integration of appropriate technology into the mathematics classroom, technology that helps students

make connections to key concepts or helps develop mathematical ways of thinking, can improve student engagement and conceptual understanding (Jones & Healy, 2019), which then can focus learning to enhance student outcomes (Smith et al., 2020). However, not all technology appropriately supports learning and thus not all technology should be used in the classroom. While many types of technology may be easy to use and provide various data for teachers and teacher leaders to consider, appropriate technology should be accessible and promote participation (Shappee, 2019). Purposeful and appropriate technology does not replace teaching or learning but rather it provides a space to accentuate and adapt the learning for all students; to develop mathematical ways of thinking and to make stronger connections to key concepts and procedures.

The purposeful incorporation of appropriate technology also aligns with broader educational goals of promoting inquiry-based learning, fostering critical thinking, and developing mathematical habits of mind (Wang & Woo, 2018). Additionally, technology prepares students for success in an increasingly digital society by enabling them to explore mathematical concepts in dynamic and interactive ways that mirror real-world applications. But the appropriate integration of technology is not limited to developing students' mathematical competencies. The integration of technology can also address the diverse learning needs of students, providing differentiated instruction and scaffolding support to ensure equitable access and opportunities for all learners (Gomez et al., 2021). For instance, language translation tools or dynamic sketch tools that create a precise drawing from a rough sketch would help those students with fine motor difficulties. For NCSM and other leaders of mathematics, equitable access to the learning of meaningful mathematics is the core of our work and as such the purposeful incorporation of technology needs to support this work.

Addressing Concerns and Challenges

History tells us that the advent and implementation of technology in new contexts can bring tremendous opportunities and legitimate concerns (Earle, 2002). When integrating technology into the mathematics classroom, it is imperative to navigate the concerns and challenges that accompany these transformative opportunities (International Society for Technology in Education, 2023)

For example, Martinez and Chen (2024) underscores the importance of addressing disparities in access to digital resources and devices. As teacher leaders, advocating for policies and initiatives that bridge the digital divide becomes paramount. Providing the necessary infrastructure for schools, including proper internet connectivity and technological support, is a first step, though not sufficient in itself in making participation in technology-enhanced learning experiences more equitable. Likewise, replacing human instruction with time on a computer, what some refer to as "adaptive programming," as a means of integrating technology is not purposeful and is rarely what is best for students. Furthermore, Wilson and Adams (2023) highlight the significance of educators' readiness and proficiency in integrating technology effectively. This means prioritizing professional learning opportunities becomes crucial. By empowering educators with knowledge, skills, and pedagogical strategies through on-going and collaborative

classroom-embedded professional learning, they become more confident and proficient in leveraging technologies. Lastly, the need for robust safeguards and protocols to protect student data and privacy cannot be understated (Taylor & Nguyen, 2022). Compliance with laws and regulations, alongside implementation of security measures, ensures responsible use of technology; transparency, accountability, and ethical practices in data handling foster trust among students, parents, and stakeholders.

Broadening the Use of Technology

There is ample research to support how technology can be used to support learning in the classroom (Cheung & Slavin, 2013; Clark et al., 2016; Dalby & Swan, 2019; Ran et al., 2022). However, viewing the integration of technology only in this light limits the ways teachers and teacher leaders can leverage technologies to support all students. And, with the continued advancements of emerging and updated digital tools, such as educational AI platforms and adaptive digital games to support the teaching and learning of mathematics, there is also a need for mathematics teachers and mathematics teacher leaders to learn how to purposefully integrate these digital tools. In light of these considerations, embracing effective and appropriate technology in mathematics education is not merely a matter of technological adoption but a strategic imperative for fostering deeper conceptual understanding, promoting mathematical literacy, and nurturing the next generation of innovators and problem solvers.

Educational Artificial Intelligence Tools

At this time, AI in education is often used as an advanced content creation and analytic tool. Educational AI tools have the potential to help mathematics teachers and teacher leaders be more creative and efficient in developing learning experiences, assessments and modifications to support various students. Because effective mathematics teacher leaders often collaborate with grade level and/or content teams to determine how best to support learning (Kanold et al., 2018), these teams can also leverage educational AI tools to consider adaptations and alternatives to current units of study, develop stronger lesson plans, and/or create common assessments. Teacher teams can collaborate with AI-driven learning modules to create personalized mathematical exercises, based on individual student performance and learning needs, in a fraction of the time often spent developing personalized experiences. These modules can adapt in real-time to provide targeted support and challenge, enhancing student engagement and learning outcomes for all students. However, it is recommended that these collaborative teams include mathematics leaders and other school/district curriculum leaders to ensure generated materials align with school/district goals.

Additionally, mathematics teacher leaders can integrate educational AI-created resources in a variety of ways to provide students with personalized support and feedback. Some learning platforms already use AI algorithms to analyze student responses and tailor instruction to their specific needs, helping to foster mastery of mathematical concepts. Knowing how to leverage and incorporate these into units of study can further help teachers target just-in-time learning and tailor students' instructional needs. Mathews and Evans (2023) stress the importance of teacher leaders aligning the integration of educational AI tools with established mathematics curricula, emphasizing these tools should complement high-leverage instructional practices. This also means that as mathematics teacher leaders, it is crucial

for us to know how to support teachers in critically engaging students with AI tools; passive receivers of information does not help one be a critical thinker or problem solver. Encouraging students to ask challenging follow-up questions and to verify their understanding of concepts is central to learning mathematics. Using educational AI as a cognitive tool in this way can help teachers design experiences to accomplish these goals. For example, teachers can leverage educational AI tools to help facilitate mathematical argumentation, allowing students to construct and critique arguments developed with AI systems. This process can help refine students' thinking and understanding of mathematical concepts. That is, emerging technologies like educational AI tools do not replace the need for skillful and adaptive teachers or the decisions they make to create rigorous, inclusive and flexible learning experiences. Rather, educational AI tools can transform teacher practices by providing new ways to approach instruction and foster deep learning of mathematics.

Furthermore, the integration of AI-generated visualizations represents a promising avenue for supporting learning in mathematics. Educational AI tools possess the capability to dynamically create interactive graphs, models and simulations, thereby facilitating a deeper exploration of mathematical relationships. These visualizations offer students opportunities to consider key mathematical concepts and relationships by manipulating variables, observing changes in real-time, and visualizing abstract ideas in concrete terms. The unique advantage of AI-developed representations lies in its ability to automate and personalize these visualizations in real-time, adapting to individual students' questions and facilitating deeper exploration and critical evaluation of mathematical concepts. Thus, by interacting with dynamic visual representations, students can develop a more intuitive understanding of mathematical principles as they are able to see how different factors affect the outcome of equations or geometric objects, thereby improving their conceptual understanding (Means et al., 2016). Current research continues to show that the use of visual representations to develop deeper mathematical connections to key concepts increases students' understanding of these concepts (Chan et al., 2022; Yeo & Webel, 2024) as well as their mathematical reasoning and problem solving skills (Herbel-Eisenmann et al., 2016; Trouche et al., 2019). As such, the potential for educational AI tools to advance students' conceptual understanding and mathematical thinking by quickly and easily manipulating, modifying or otherwise visualizing mathematical relationships must be considered.

Digital Games and Virtual Manipulatives

Digital games have become increasingly recognized as effective tools for enhancing the teaching and learning of mathematics. Digital games can offer dynamic and engaged learning experiences for students particularly since digital games can foster active learning and improve motivation (Gee, 2003; Plass et al., 2014). However, not all games have the same impact on student learning as not all digital games are designed around key features that appropriately support students' conceptual and procedural understanding.

Some of these key features that mathematics teachers and teacher leaders should look for include the ways in which games simultaneously link visual representations to student mathematical actions, incorporate creative variation so students can find a variety of solution pathways, focus constraints for learning and integrate scaffolding supports, as well as provide timely and corrective feedback (Bullock et al., 2021; Falloon, 2013). For example, when students can manipulate mathematical objects

in relation to the mathematics understudy, like moving a number on a number line, and can see how the movement along the number line relates to symbolic representations and mathematical relationships, and then get immediate feedback on key aspects of the concepts, students' mathematical understanding increases (Moyer-Packenham et al., 2019). This means mathematically appropriate digital games with the right design features can supplement core instruction and enrich students' learning.

Furthermore, virtual manipulatives, which are a technology-based visual representation that allows students to interact with, help students explore and and otherwise manipulate mathematical constructs in order to develop complex mathematical understandings (Moyer-Packenham & Bolyard, 2016). By providing a platform for "hands-on" practice, students can apply mathematical concepts, build stronger connections between concepts, and can discuss key aspects to support their learning even when traditional physical models are not present (Clark et al., 2016). Furthermore, adaptive algorithms embedded in many digital math games personalize the learning experience by adjusting difficulty levels to match individual student proficiency, promoting personalized learning (Barab et al., 2019). The immediate feedback mechanisms inherent in these games enables students to identify and correct mistakes in real-time, facilitating continuous improvement and self-assessment (Hwang et al., 2020). Additionally, the immersive nature of digital games can spark curiosity and intrinsic motivation among learners (Li et al., 2019), leading to deeper exploration of mathematical concepts and the development of critical thinking and problem-solving skills.

How Mathematics Teacher Leaders Can Implement Our Position

Mathematics teacher leaders hold the key to transforming mathematics education. When teacher leaders help teachers embrace and integrate emerging technologies, such as online games and educational AI tools, these teachers can efficiently create dynamic, engaging learning environments that empower students to become confident, critical thinkers. In support of this position statement, NCSM offers the following recommendations:

Advocacy and Awareness

Mathematics teacher leaders can advocate for the equitable systematic integration of effective technologies in mathematics classrooms to enhance curriculum, pedagogy, assessments, and approaches to equity. This involves promoting awareness among educators about the benefits of technology integration in fostering meaningful and effective learning experiences. Likewise, mathematics teacher leaders should also advocate for the ethical and responsible use of technology, online games, and educational AI tools in mathematics classrooms by emphasizing the importance of data privacy, security, and compliance with regulations, as well as promoting transparency, accountability, and ethical practices in data handling.

Providing Professional Development

Mathematics teacher leaders can provide classroom-embedded professional learning sessions and follow-up workshops to equip educators with the knowledge, skills, and pedagogical strategies necessary for effectively integrating technology, online games, and generative AI into mathematics instruction. These sessions can focus on enhancing student engagement, facilitating personalized learning

and differentiated instruction, cultivating essential skills, and promoting inclusivity, as supported by research.

Collaborating with Grade-Level or Content Teams

Mathematics teacher leaders can collaborate with grade-level or content teams to explore how best to leverage technology, online games, and educational AI tools to support learning for all students. This involves brainstorming ideas, examining potential resources together to consider opportunities or challenges with the resource, and critically examining AI-created modifications that cater to diverse learning needs and promote personalized learning experiences. Likewise, mathematics teachers have an important relationship with their building-level or district-level technology personnel when it comes to implementing various technologies or resources. Continued collaboration with these experts is not only important but may also be how the classroom-embedded professional learning begins and then nurtures.

Continuously Evaluating and Reflecting

Mathematics teacher leaders should continuously evaluate the effectiveness of technology integration efforts and reflect on lessons learned. This involves gathering feedback from educators and students, assessing learning outcomes, and adjusting implementation strategies as needed to optimize student engagement, understanding, and achievement in mathematics. This process of continuous evaluation also means critically examining the technologies in use within a classroom, building, and/or district and asking if the technology is as responsive as educators need to be.

Summary

As mathematics teacher leaders, it is imperative to recognize the profound impact that technology can have on enhancing mathematics education. By creating equitable learning experiences for all students, in providing tools to showcase the relevance of mathematics in our world and in helping teacher teams align curricular resources and assessments with instructional practices, emergent technologies become a cornerstone of quality mathematics instruction. However, this also means that mathematics leaders integrate insights from research into practice; we navigate concerns and challenges with a proactive and informed stance. As mathematics teacher leaders, our commitment to equity, ethics, and excellence in mathematics education drives us to lead by example. This means advocating for policies, practices, and initiatives grounded in research to ensure equitable access to technologies that empower educators and prioritizes student well-being in the digital age.

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