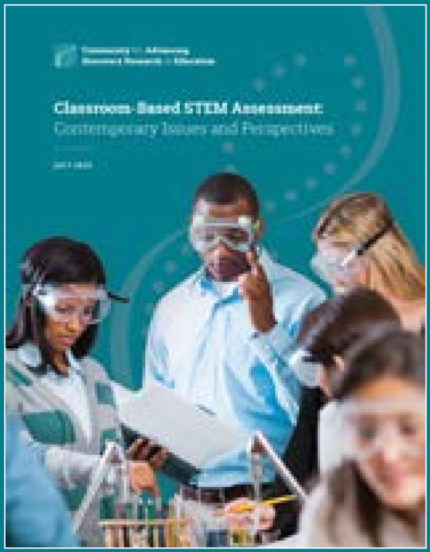
Community for Advancing Discovery Research in Education

Classroom-Based STEM Assessment: Contemporary Issues and Perspectives

EXECUTIVE SUMMARY



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This report takes stock of what we currently know as well as what we need to know to make classroom assessment maximally beneficial for the teaching and learning of STEM subject matter in K–12 classrooms.

It draws inspiration from the cumulative body of research on assessment in STEM education that has accrued over the last two decades, with particular emphasis on work funded by the National Science Foundation (NSF) through its Discovery Research PreK-12 (DRK-12) funding program. The program has long held that: "For assessment to be a driving knowledge engine that moves STEM education forward it must be integrated with systems of learning and teaching, with specific attention paid to the needs of practitioner communities and how assessments would be used in formal education settings."[1] The major sections in this report, individually and collectively, focus on critical issues regarding assessment integration and use at the classroom level.

This work is sponsored by CADRE, an NSF-funded network for STEM education researchers endeavoring to improve education in science, technology, engineering, and mathematics through various information-sharing and community-building mechanisms (**https://cadrek12.org**). The report responds to multiple research and policy developments over the last two decades, including (a) the changing landscape of policy and practice discussions regarding desired outcomes from the educational system for the 21st century, (b) related changes in the content standards and student outcomes expected in the STEM disciplines, (c) explications of the science underlying design of educational assessments to support their varying forms and functions in the educational system, (d) evolution of theory and research on the nature and development of STEM disciplinary learning and its implications for classroom instruction and assessment, and (e) a shift from the emphasis on large-scale standardized testing to greater focus on the uses of assessment in the classroom as part of ongoing teaching and learning.

Two important societal level factors make the discussion of classroom instruction and assessment particularly pertinent. The first is increased urgency to address long-standing disparities in opportunities to learn and educational outcomes for underserved and marginalized populations and the role of assessment in reducing differences in opportunities and outcomes rather than reifying them. The second is rapid growth of student access to technologies and the development of potent computational tools, such as data analytics and artificial intelligence (AI), to support the integration of classroom assessment into instructional practices, including enactment of formative assessment practices.

Through consultation with experts in the field, the editors chose five thematic threads to organize key ideas and perspectives on this important area of STEM education research. The report authors have captured these threads in five sections, each of which represents different and important integrations and perspectives on the knowledge and practice of STEM classroom assessment. What follows is a summary of each section's content and its recommendations.

1 National Science Foundation (2020). *Discovery Research PreK-12 (DRK-12): Program solicitation NSF 20-572*.

Section 1. Connecting Classroom Assessment with Learning Goals and Instruction through Theories of Learning

Connecting Classroom Assessment with Learning Goals and Instruction through Theories of Learning emphasizes the importance of aligning classroom assessments with STEM learning goals and instruction so that they can be used as part of ongoing instruction to monitor students' progress in learning and to support students in future learning.

The authors put forth the position that models of how learning progresses in the STEM disciplines, often referred to as either learning progressions or learning trajectories, offer a compelling and principled way for developing assessments that align with learning goals and instruction and cohere with learning theory. This alignment is critically important for ensuring that assessments reflect contemporary views on learning in STEM disciplines and that they serve to provide insight into how students' disciplinary knowledge and practices are developing over time with appropriate instruction. The authors discuss how student response data from these kinds of assessments can potentially be used to inform instructional decision-making and improve the teaching and learning process. The section describes several NSF DRK-12 projects that are using learning progressions to guide the design and use of classroom assessments. It concludes with the following three recommendations for future research and development of classroom-based STEM assessments:

> **Recommendation 1-1.** ***As learning progressions continue to be mapped out and empirically validated in the STEM disciplines, it will be important to focus research efforts on their use as a framework for developing and using assessments that inform instructional decision-making.***
>
> **Recommendation 1-2.** ***Standards and expectations for STEM proficiency have changed substantially and assessments for today's STEM classrooms should reflect these contemporary perspectives on learning in the disciplines.***
>
> **Recommendation 1-3.** ***More research work is needed to help us better understand the ways teachers can generate meaning from assessment results that will transform students' opportunities to learn.***

Section 2. Assessment for Learning

Assessment for Learning reviews the conceptual and empirical literature on formative assessment—what it is, why it matters, and evidence for its efficacy—and connects this classroom assessment practice to research on learning progressions or trajectories.

It illustrates what is possible in the STEM classroom, with detailed illustrations of assessment connected to the early learning of mathematics, while simultaneously highlighting the challenges of doing so. Drawing upon NSF DRK-12- funded projects, it provides examples of designing classroom assessment closely aligned with learning trajectories for important aspects in the development of early mathematical knowledge and skill. The section reviews evidence in support of the impact and efficacy of formative assessment on student learning, including concerns in the literature on evaluation of outcomes. It also highlights some of the major conceptual and empirical work that remains to be done to enable teachers to engage productively in the assessment for learning process as part of their overall classroom instructional practice and includes suggestions for future research and development. Recommendations coming out of this discussion follow:

> **Recommendation 2-1.** ***High-quality assessment development and validation work is needed for classroom-based STEM assessments that can be used to improve teaching and advance learning.***
>
> **Recommendation 2-2.** ***Ongoing research is needed about the nature and efficacy of professional learning for supporting teachers to implement formative assessment effectively.***
>
> **Recommendation 2-3.** ***Development, iterative refinement, and validation of learning progressions across all the STEM disciplines should continue and is especially encouraged in emerging areas of technology, engineering, and computer science education.***

Section 3. Equity and Justice in Classroom Assessment of STEM Learning

Equity and Justice in Classroom Assessment of STEM Learning examines the conceptions of equity and justice in the emerging literature on STEM learning and considers how these contemporary perspectives can be centered in STEM classroom assessment.

The authors recognize assessment as one of three central components of a classroom learning environment—consisting of curriculum, instruction, and assessment—and argue that centering equity and justice is a transformative act that will require accompanying transformations in curriculum and instruction. Since all three interact within a classroom to shape STEM learning, all three must be transformed for assessment to fully support teaching and learning. The section presents descriptions of several DRK-12 projects to illustrate how equity and justice are addressed in classroom assessments of STEM learning. While many projects focus on equity in assessment, projects that center justice are only beginning to emerge. Recommendations coming out of this section follow:

> **Recommendation 3-1**. ***Contemporary perspectives of equity and justice should be central in STEM classroom assessment design and practice.***
>
> **Recommendation 3-2**. ***STEM education research should take a more expansive view of assessment as integral to curriculum and instruction and consider that all three must work together toward new futures in STEM learning.***
>
> **Recommendation 3-3**. ***In the development of assessments that center equity and justice, designers should build assessments in concert with educators, learners, and communities.***
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> **Recommendation 3-4**. ***Assessment work should embrace a wide and inclusive view of what constitutes historically minoritized populations.***

Section 4. Teacher Knowledge and Practices for Assessment.

While there is a growing knowledge base on supporting student learning through formative assessment, ultimately success hinges on whether teachers understand the formative use of assessment and can incorporate it into their classroom practice.

Formative assessment is thus a fundamental teaching practice that must become part of pre- and in-service teacher assessment literacy and professional development (PD). In this section, the authors draw on over two decades of research on teacher assessment literacy and practice to argue that teachers need support in three domains to carry out high-quality assessment in their classrooms. First, they need models of student learning that are empirically grounded, developmental, and interpretable for classroom application. Second, teachers need feasible strategies for eliciting valid evidence of student thinking. Third, teachers need tools that support interpretations of the generated evidence in terms of the learning model. The section also makes the argument that learning progressions or trajectories are a key vehicle to support teachers in engaging in high-quality classroom assessment practices. Two illustrative examples from NSF's portfolio help bring alive these ideas on teacher knowledge and preparation for classroom assessment: (1) a learning progression to support the development of statistical reasoning and (2) a PD model for improving chemistry teachers' formative assessment practices. The section ends by identifying challenges and providing recommendations for future directions in STEM teacher preparation, including the unique challenges presented by new subjects, such as computer science and engineering. Recommendations coming out of this section follow:

> **Recommendation 4-1.** ***New assessment development projects should attend to the knowledge and practices teachers need support in, and design assessment systems with features to support professional learning and uptake in practice.***
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> **Recommendation 4-2.** ***Disciplinary-specific models of student cognition should be explicitly articulated in ways that can be examined apart from the assessment tools designed to elicit thinking, and so that teachers can understand them and make use of them.***
>
> **Recommendation 4-3.** ***Assessment to be used in classroom practice should elicit student ideas and reasoning for the purpose of monitoring and advancing individual and collective learning.***
>
> **Recommendation 4-4.** ***STEM practitioners should undertake cycles of designing, implementing, and reflecting with colleagues to improve assessment practice over time, and develop shared strategies for dealing with the practical challenges of designing and implementing assessment.***

Section 5. Technology-Based Innovative Assessment.

A large body of research has studied how technologies such as games, virtual/augmented reality, AI, and learning analytics have been used for developing classroom-based assessments.

In this section, the authors examine critical developments in technology-driven, classroom-based innovative assessment practices using a framework organized around (a) assessment of complex constructs, (b) assessment functionality related to evidentiary inferences, and (c) automaticity of assessment tasks. The authors aim to identify the critical roles that emerging technologies play in assessment practices related to these three dimensions. Of particular focus is emerging computational tools, such as educational learning analytics (ELA) and AI, and their role in the form and functionality of classroom-based assessment. The section concludes with how prior work and emerging technologies come together to point toward future directions in classroom-based assessment development, implementation, and research. Of particular importance will be the role of teachers and teacher PD in harnessing the potential of these emerging assessment technologies in classrooms. Recommendations coming out of this section follow:

> **Recommendation 5-1.** ***Those responsible for the design and development of technology-based innovative STEM assessments should continue to explore how technology can work with teachers and students to support and improve the effectiveness, equity, and feasibility of complex STEM teaching and learning.***
>
> **Recommendation 5-2.** ***Cross-disciplinary teams of experts from diverse fields, including computer science, STEM education, psychology, assessment, and ethics (among others), are needed for envisioning, designing, and ensuring the development of AI-driven classroom-based assessment systems that benefit all students and teachers.***
>
> **Recommendation 5-3.** ***Research is needed on the distribution and operationalization of real-time assessment data with regards to what is delivered directly to students, what goes to teachers to use as part of their classroom decision-making and orchestration, or some combination thereof.***

The full set of recommendations are listed in the conclusion to the report. In addition to the recommendations, the editors put forth the following five priority areas with implications for research, practice, and policy:

Anchoring the work of assessment in STEM classrooms. By its very nature, work on classroom-based assessment cannot exist in isolation of other key elements of classroom practices. That is, assessment work needs to be done *in service* of instruction, which, in turn, should be driven by standards-based curriculum. This work has to be sensitive to the diverse set of cultural resources, ways of knowing, and ways of expressing oneself that students bring to the classroom. Moreover, technologies need to be designed and utilized to help solve the challenges of classroom-based assessment. To accomplish this, expertise needs to be drawn not only from different disciplinary areas (e.g., computer science, psychology, education), but also from instruction, taking into account contemporary perspectives on classroom activity and the students and teachers in today's classrooms.

Assessment design for integrated STEM knowledge and proficiency. Research on learning progressions and learning trajectories points both to the unique disciplinary-specific knowledge students need and the pathways they follow to develop these understandings. However, the increasing emphasis on integrated STEM also has led to discussion of progressions and trajectories and their associated assessments that need to cut across traditional disciplinary boundaries. If there is one thing all of the research on developing progressions and trajectories has shown us, it is how much more work is still needed within and across disciplines. For instance, development and validation of assessments in areas such as data literacy, computational thinking, or engineering design need contexts rooted in science, mathematics, and technology. Accordingly, assessment meant for interdisciplinary learning needs to measure integrated proficiency with two or more disciplines. This work needs to be done in a way that helps uncover new, generalizable knowledge about STEM learning, but that does not result in a loss of coherent and actionable information for teachers.

Addressing challenges of curricular coherence and aligned assessment. The distributed nature of information and knowledge in the digital age has resulted in curricular resources being drawn from multiple sources that have undergone different levels of review and alignment to national and state standards. Thus, providing coherence between curriculum and assessment for teachers and students in classrooms across a district or state can pose a substantial challenge for the design, selection, and use of assessment, especially at the classroom level. Coherence can only be achieved if the curricular and assessment resources are aligned to the same learning goals and if that alignment holds not only within classrooms but across classrooms at school, district, and state levels.

Building an expanded and inclusive view for meeting the needs of student populations underserved by current assessment models and practices. While the current work in equity and justice has taken up this challenge, it will be important to continue identifying and understanding important but understudied populations (e.g., the neurodiverse), and how research with these populations can be generalized to help formulate guideposts and practices applicable more broadly. A strong approach would be to utilize the Principles of Universal Design for Learning (Hitchcock, Meyer, & Rose, 2002) to guide the design of curriculum, instruction, and assessment, providing for multiple means of engagement, representation, and action and expression. This approach has gained currency in the last two decades, especially in disciplines such as computer science, as they align well with emergent calls for equity and inclusion. Curriculum materials and assessment designed to promote equity and justice are developed in partnership with teachers, students, and communities using phenomena and problems located in place. In addition, just as recent important work has examined the intersectionality of gender and race/ethnicity, research on understudied populations, such as the neurodiverse, will need to look at the unique characteristics that emerge at the intersections.

Leveraging emerging technologies to unlock the full potential of classroom-based assessment. While there is a strong tendency to look to technologies to simply automate practices already in place, the power and potential of emerging technologies allow us to consider exciting new ways to design and deploy classroom-based assessment. By starting with the aspirational goal of instructionally informative assessment, we can look to technologies to provide ways of achieving what has heretofore not been scalable, along with instructional insights that were previously opaque to teachers, students, and researchers.

The priorities mentioned above can only be fully realized through reciprocal partnerships involving STEM education practitioners and stakeholders. STEM teachers, for example, will need to become integral partners with researchers and developers to co-design and implement technology-enhanced classroom-based assessment tools that accurately reflect the knowledge and abilities of all students in their classrooms. With the collaborative effort of teachers, researchers, developers, and other relevant stakeholders, including school district STEM leaders among others, we can come to better understand what teachers need and when they need it. As with the design and deployment of the assessments themselves, technological improvements may point to novel approaches to this challenge.

As highlighted in this report, substantial progress has been made in pursuing the integration of assessment with teaching and learning in STEM classrooms, but many critical issues remain within and across the STEM disciplines. An ambitious, multidisciplinary agenda of research, development, and implementation is needed to fully reap the benefits that can accrue from well-designed and appropriately implemented assessment tools and practices for the STEM classroom.

Acknowledgments

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Community for Advancing Discovery Research in Education

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CADRE helps DRK-12 researchers share their methods, findings, results, and products inside the research and development community and with the greater public so that we are:

- **Better informed** about the work that is being done,
- **Continually building** on what we have collectively learned,
- **Working with our schools, communities, and policy-makers** to make our findings and products accessible and usable, and
- **Progressively able to address new and more challenging issues—**including those issues that extend beyond the limits of what any singular research project can impact.

Together, we can make a larger impact on policy, research, and education.

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