Community for Advancing Discovery Research in Education

Classroom-Based STEM Assessment:
Contemporary Issues and Perspectives

RECOMMENDATIONS

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Acknowledgments

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Recommendations for Classroom-Based STEM Assessment

The STEM education community is at a pivotal moment in in how we approach assessment and its role in the teaching and learning process. Major developments over the past two decades in STEM education and classroom assessment provide a compelling argument for shifting the focus of assessment toward the classroom where its most powerful benefits can be realized. The increased emphasis on diversity, equity, and inclusion in education puts increased scrutiny on assessment practices and points to the need for more proximal approaches that are contextualized in the places where students learn and are sensitive to individual differences. Similarly, emergent technologies, especially those centered on artificial intelligence (AI) technologies, are providing potent tools for teachers to use in classrooms to assist with assessment that can guide more individualized instruction. In this arena too, there is a pressing need to build more equitable and socially just technology-based assessment systems. As a classroom-based activity necessarily impacted by both calls for increased attention to equity and justice and powerful, emerging technologies, the need for substantive professional development is once again brought to the forefront.

The following recommendations are based on the findings and analysis presented in the report ***Classroom-Based STEM Assessment: Contemporary Issues and Perspectives***.[1] They represent what we currently know as well as what we need to know to make classroom assessment in STEM maximally beneficial for the instructional practices of teachers and the learning outcomes of students.

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

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.

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.*** Learning progressions have tremendous potential to guide the design of classroom-based assessments for formative purposes and the role they can play in classroom-based assessment remains an important area for researchers.

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.*** Notably, research and development are needed on specific ways in which classroom-based assessments can be designed to reflect multiple ways of knowing in STEM disciplines and that honor and reflect students' cultural practices and funds of knowledge.

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.*** It is widely recognized that alignment among curriculum, instruction, and assessment is integral to coherent and robust STEM teaching and learning, yet there is still much to be learned about how assessments and assessment results can be used in instructionally supportive ways.

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1 Please refer to the complete report to delve deeper into the topic. The report is a product of the Community for Advancing Discovery Research in Education (CADRE) committee on classroom-based assessment. CADRE connects STEM education researchers funded by the National Science Foundation's Discovery Research PreK-12 (DRK-12) program to share their methods, findings, results, and products with the research and development community and the greater public to better inform and impact policy, research and education. The activity was funded by the National Science Foundation, Grant # 2100823. Any opinions, findings, and conclusions or recommendations expressed in these materials are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

2. Recommendations for Assessment for Learning

As opposed to assessment of learning that is generally summative in nature, formative assessment entails assessment for learning. It is characterized by the effort to collect information about the state of students' thinking and performance so instruction can be tailored to further progress. Learning progressions describe the development of sophistication in students' thinking and performance related to STEM discipline-specific topics. Aligning classroom assessments with learning progressions may improve the relevance and usefulness of classroom-based assessment for informing instruction and guiding future learning opportunities.

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.*** Validation requires rigorous design coupled with multiple sources of evidence supporting assumptions about what the designed tasks are assessing and their capacity to reveal important student differences that are conceptually and instructionally meaningful.

Recommendation 2-2. ***Ongoing research is needed about the nature and efficacy of professional learning for supporting teachers to implement formative assessment effectively.*** The shift toward assessment for learning often presents conceptual issues for teachers in understanding and implementing the formative assessment process integrated with curriculum and instruction.

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.*** This work is critical for establishing a continuum within and across grade levels with various implications for classroom STEM assessment.

3. Recommendations for Equity and Justice in Classroom Assessment of STEM Learning

Equity and justice should be placed at the center of STEM learning environments and centered in assessment of STEM learning. For equity and justice to be centered in classroom assessment, it must also be centered in curriculum and instruction so that all three major components of the learning environment can work effectively together. Increasingly, developers and practitioners are taking up equity and justice perspectives in developing or adapting assessments that are responsive to the learners who will be participating in them. To accomplish this, an expansive view of both equity and justice in assessment needs to be undertaken. Researchers and practitioners need to embrace their unique roles as they work on developing assessments and associated professional development materials that are responsive to the learning needs of all students and integral to curriculum and instruction.

Recommendation 3-1. ***Contemporary perspectives of equity and justice should be central in STEM classroom assessment design and practice.*** It is important to recognize that centering equity and justice in STEM classroom assessment is a transformative act that will require accompanying transformations in curriculum and instruction. Also noteworthy is that contemporary STEM education research seems to be taking approaches associated with equity more than justice in assessment. Accordingly, research should move toward an increased emphasis on incorporating justice in classroom assessment of STEM learning.

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.*** This view is needed to better understand students' experiences with assessment, their opportunities to engage in meaningful learning, the ways they are supported through instruction, and how their ideas and experiences are represented in and taken up in 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.*** STEM education practitioners and leaders are ideally positioned to center equity and justice in developing or adapting curriculum materials and assessments and in implementing instructional approaches that build on their relationships with students, families, and communities. In particular, teachers need spaces to reflect upon the role that their classroom assessment plays in assuring that all students have opportunities to engage in STEM learning.

Recommendation 3-4. ***Assessment work should embrace a wide and inclusive view of what constitutes historically minoritized populations.*** The newly energized work on bringing equity and justice to STEM classrooms needs to embrace goals that encompass a wide range of unique populations, which includes not only racial and ethnic cultural diversity, but also physical and neurodiversity as well. Better understanding of what resources different populations bring to the classroom will help in developing and deploying classroom-based assessments that allow all students to demonstrate their abilities and articulate where and how support is needed.

4. Recommendations for Teacher Knowledge and Practices for Assessment

It is widely recognized that formative assessment is fundamental to high-quality teaching and learning, yet it is among the most challenging practices to embed in everyday instruction. The promise of classroom-based STEM assessment rests on the extent to which teachers understand the formative use of assessment and can incorporate it into their instructional practice. Accordingly, teacher professional learning for assessment, with accompanying resources and supports to transform professional learning into practice, are paramount.

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. Closely related is identifying high-leverage strategies that can bring about change in classroom-based assessment practices at a large scale.

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.*** Cognitive models can serve to support teachers, curriculum and assessment developers, and researchers to share a vision of student learning that is grounded in research in a particular STEM domain.

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.*** To accomplish this, prompts should be designed to allow for diverse ways students can demonstrate learning and performance. This is needed so that teachers can gain insights to support further learning rather than only judging students' ideas in relation to conventional ideas and models that professional communities use.

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.*** Collaborative planning and conversations can help move teachers away from using traditional or narrow assessment techniques and formats and toward trying new ways for using assessment to support STEM learning.

5. Recommendations for Technology-Based Innovative Assessment

The development of technology-based innovative assessments is already underway and expanding the boundaries for what assessment can look like in STEM classrooms. Recent progress in a range of areas including AI, real-time assessment, digital technologies, and virtual reality combined with new techniques from measurement science and data analytics are playing critical roles in enabling innovative assessment practice. Emerging technologies enable real-world simulations of phenomena and problems; support the eliciting, representing of complex performance; efficiently analyze both response and response process data; aid in displaying and interpreting performance; transform individual and collective data into actionable information; and stand to reduce many of the practical challenges of formative assessment.

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.***

Compelling research and development is underway, but more work is needed on how assessment technologies can be operationalized for formative-focused use in classrooms.

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.*** While there is tremendous promise with AI-driven technologies, there are also many potential pitfalls and new, challenging issues regarding privacy, fairness, equity, and access that will need to be addressed in parallel with the development of these emerging technologies.

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.*** As both the type and quantity of assessment data evolve, there is a need to better understand how data can be organized, represented, and deployed with next-step guidance to students and teachers within the differing time frames of the classroom assessment orchestration loop.

Priority Areas with Implications for Research, Practice, and Policy

Anchoring the work of assessment in STEM classrooms. 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 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 new disciplines like computer science, as they align well with emergent calls for equity and inclusion. Curriculum materials 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 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.

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.

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CADRE is a network for STEM education researchers funded by the National Science Foundation's Discovery Research PreK-12 (DRK-12) program. Through in-person meetings, a website, common interest groups, newsletters, and more, CADRE connects these researchers who are endeavoring to improve education in science, technology, engineering, and mathematics in, and outside of, our schools.

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
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