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What are STEM Indicators and Why Do They Matter for Practitioners?

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Abstract. The article reports on the features of the National Research Council's 14 *indicators* for monitoring progress in K-12 education in science, technology, engineering, and mathematics (STEM) and shares recent work analyzing the many ways state and national databases categorize and label information. The report offers insights about developing and using shared data standards. Cross-region and cross-state comparisons of opportunities and outcomes for students, teachers, and administrators are important for monitoring equitable progress and can drive policy and professional decisions about K-12 STEM education.

Box 1. Basic but currently unanswerable questions about education in the U.S.:

- What opportunities to learn mathematics and science do students have in elementary school?
- What is the quality of those learning opportunities?
- How do experiences differ from district to district or state to state?
- What opportunities for professional growth do teachers have in mathematics and science and computer science and engineering?
- Now there are schools that focus on science, technology, engineering, and mathematics (STEM) but what makes a school or program a STEM school or program?
- More broadly, what data does a district keep and monitor, related to which classes for students and professional activities for teachers and leaders to answer questions like these?

The answers to the above and other critical questions about the quality, content, and processes in U.S. education are needed for decision-making by leaders and communities across the nation. While a few of the questions have been addressed in some ways in National Science Board publications (every 2 years, 2006-present), by and large the listed questions have been unanswerable because the data needed has been gathered and stored in isolated, unconnected ways.

For instance, suppose a group of community members and leaders needed to know about the similarities and differences in the educational landscapes in California, Ohio, and Georgia, perhaps about expectations for teacher knowledge. Each state's office of teacher credentialing might have some information. However, each office would have its own way of documenting "content knowledge for teaching" – perhaps through degree programs, or performance on nationally standardized assessments of knowledge for teaching. The varied data are stored under differing names in each state database. Also, within states, each district or local education authority tracks teacher qualification and reports to a data system in the state department of education. However, the state level data system used to document what is happening for students in schools may or may not include data from the state's office of teacher credentialing. At the same time, regional accreditation of teacher preparation programs involves criteria that may or may not match states' and has different standards for collecting, naming, storing, and sharing data. Thus, though data might exist, it is virtually impossible to make a reasonably efficient comparison across states because the names of the categories of data differ across sites within states and across states, just as the definition of what is associated with each named data element is different and processes for retrieving the data differ from place to place.

In 2013, the National Research Council released *Monitoring Progress Toward Successful K-12 STEM Education: A Nation Advancing?* The report had a set of "indicators" of success in science, technology, engineering and mathematics (STEM) education. These assertions about what needed to be measured built on the existing standards-based conversation about quality in STEM education. Standards provide the foundation for the system of curriculum, instruction, and assessment in schools. The 14 indicators, summarized in Table 1, give direction for how to go about measuring change in that system. For example, answering the basic questions in Box 1 requires information about the measures in Indicators 1 through 8.

Table 1. Indicators for Monitoring Progress Toward Successful K-12 STEM Education.

1. Number of and enrollment in different types of STEM schools and programs in each district.
2. Time allocated to teach science in grades K-5.
3. Science-related learning opportunities in elementary schools.
4. Adoption of instructional materials in grades K-12 that embody research-based standards such as the *Common Core State Standards for Mathematics* (CCSS-M, 2010) or *Next Generation Science Standards* (NGSS, 2013).
5. Classroom coverage of content and practices in rigorous and research-based standards (e.g., the CCSS-M or NGSS).
6. Teachers' science and mathematics content knowledge for teaching.
7. Teachers' participation in STEM-specific professional development activities.
8. Instructional leaders' participation in professional development on creating conditions that support STEM learning.
9. Inclusion of science in federal and state accountability systems.
10. Inclusion of science in major federal K-12 education initiatives.
11. State and district staff dedicated to supporting science instruction.
12. States' use of assessments that measure the core concepts and practices of mathematics and science disciplines.
13. State and federal expenditures dedicated to improving the K-12 STEM teaching workforce.
14. Federal funding for the research identified in the NRC (2013) report (e.g., research that disentangles the effects of school practice from student selection, recognizes the importance of contextual variables, and allows for assessment of student outcomes across multiple years/grades).

Note: Based on the report by Lach (2016), statements for Indicators 1, 4, 5, 10, and 14 have been extended to improve clarity when presented outside the context of the original NRC report.

Background

The indicators serve multiple purposes. They provide a common language for states to communicate internally and externally about STEM education efforts as well as being a foundation for national-level reporting that could support progress towards the three goals for education in the STEM disciplines stated by the National Research Council (2013):

- Goal 1. Expand the number of students who ultimately pursue advanced degrees and careers in STEM fields and broaden the participation of women and minorities in those fields.
- Goal 2. Expand the STEM-capable workforce while broadening the participation of under-represented groups in that workforce.
- Goal 3. Increase STEM literacy for all students, including those who do not pursue STEM-related careers or additional study in the STEM disciplines.

The intent of the NRC report was to identify ways to monitor changes in the system and to determine how (and if) those changes could be characterized as progress. Measuring progress in each indicator requires data. The indicators are *n*ot standards. In particular, "more" of something does not mean "better" or "progress." Rather, the indicators describe data about characteristics for which deeper knowledge can be useful in decision-making by educational stakeholders, from parents, teachers, and principals to superintendents to state and national educational policy-makers.

Early Findings from an Examination of State Level Data Systems (SLDS)

Even as the NRC was identifying the indicators, several National Science Foundation-funded projects were launched to begin the complicated work needed to allow cross-district and cross-state communication using educational data. This short report highlights one of those efforts. The driving question for the work was whether current state level data systems (SLDS) collect data sufficiently robust, comprehensive, and aligned to the indicators to allow monitoring of progress in the areas identified by the NRC indicators. And, if not, what are next steps to leveraging SLDS structures to evaluate national progress?

In particular, our project looked at the potential of a national, shared, data dictionary to support within and cross-state communication about the evidence available to monitor progress in STEM education. The sources of information for our exploration were interviews, conversations, and surveys with an array of people, all of whom were professional stakeholders in the collection and use of school data: teachers, teacher-leaders at local and state levels responsible for the design and delivery of STEM professional learning for teachers, school and district leaders (e.g., principals, superintendents), state department of education leaders (e.g., those working with gathering and reporting student data and those working on teacher credentialing), and state level data system managers.

A Shared Data Dictionary. A data element consists of the name and description of a piece of data (fact or statistic). Because a data element is information for classifying or organizing data, it is often called metadata. Each SLDS data system has some form of data dictionary (i.e., a list of the kinds of data tracked by the system). Sometimes the dictionary is implicit in the design of the state database, sometimes definitions are documented for many or all types (elements) of data. Table 2 gives a few examples of data elements and their descriptions.

The Common Education Data Standards (CEDS) is a national database effort among federal and state governments, districts, and other education organizations. The goal of CEDS is to get agreement among organizations on a common set of education data elements for stakeholders to exchange, compare, and use

Table 2. Examples of Data Elements.

Element Name	Element Description/Definition
Course Title	The descriptive name given to a course of study offered in a school or other institution or organization. In departmentalized classes at the elementary, secondary, and postsecondary levels (and for staff development activities), this refers to the name by which a course is identified (e.g., American History, English III). For elementary and other non-departmentalized classes, it refers to any portion of the instruction for which a grade or report is assigned (e.g., reading, composition, spelling, and language arts).
Instructional Minutes	The total number of instruction minutes in a given session, as determined by time in class, time on task (e.g., engaged in a class), or as estimated by a qualified course designer.
Activity Title	The title for a particular activity, such as a co-curricular or extra-curricular activity.
Activity Identifier	A unique number or alphanumeric code used in the local system to identify an activity, such as a co-curricular or extra-curricular activity that is offered at an education institution.
Activity Time Involved	The amount of time the student participated in the events and procedures of an activity, such as a co-curricular or extra-curricular activity that is offered at an education institution.
Teacher Credential Exam Type	The type of examination used to assess teacher candidate's knowledge and skills. Option Set: PraxisI; PraxisII; ACTFL; StateExam; Other.
Years of Prior Teaching Experience	The total number of years that a person has previously held a teaching position in one or more education institutions.

to understand educational data within the United States (access and instructions for use of CEDS can be found at: `https://ceds.ed.gov/default.aspx`).

If the CEDS goal is achieved, it will be the main data dictionary for state and local data systems. Essentially, CEDS would have the role for educational data communication that the Miriam Webster dictionary has for written communication in the U.S.

I worked as part of a team of teachers and researchers, bringing to the work my perspective as a K-5 science education leader. Our team analyzed if and how data from State Level Data Systems (SLDS) might be used to monitor progress in the areas of the indicators and examined the degree and types of agreement between SLDS data dictionaries and the national CEDS dictionary. The aim was to understand the landscape of state and national data resources and explore what the next steps might be to support the monitoring of progress.

Professional Awareness. From the analysis of data systems, interviews with the people who maintain them, and conversations with teachers, teacher-leaders, school leaders, and state-level STEM education specialists, we found that knowledge of the NRC recommendations for monitoring progress in the 14 indicators in Table 1 was not widespread:

- Some state leaders were familiar with the ideas behind the indicators and some with the notion of common data elements, but most were not. Also, the NRC indicators were not part of the professional discourse in K-12 mathematics or science practitioners' communities. Nor was there awareness among K-12 leadership of the incomparability of data sets (i.e., the challenges of considering local work in a larger, multi-state, context was seen as insurmountable).
- The use of indicators to monitor progress as part of data-driven decision-making within a school was seen as of potential value. However, without ready access to data related to them, the indicators were not yet seen as worth including in school level conversations.
- Though the data dictionary information available through CEDS for state and district level data management was valued by STEM education teacher-leaders, it was not valued by most state level data system managers.

These tools (i.e. indicators and CEDS) can greatly enhance communications and promote efficacy toward making decisions and policies in STEM education. The implications for the use of CEDS across the national landscape include: allowing for sharing data sets among states and districts, providing a common language for drafting and disseminating policies, supports, and decision-making with greater consistency and clarity for all stakeholders in STEM education. From development and selection of rigorous curricula, school scheduling and hiring; to professional development for regular classroom and specializing math and science teachers and administrators, as well as allocation of resources, the STEM indicators and CEDS could provide an efficient and effective network of information for all education stakeholders.

Sampling of Project Results. More specifically, our team looked at indicators, 1, 2, 3, 6, 7, and 8. Across these indicators, data elements (i.e., types of data) related to Indicator 1 were most common in the CEDS and state level systems we examined. However, state level data systems rarely specified a STEM category for elementary schools; the closest available data elements were those about whether a school name indicated a STEM focus (e.g., a charter or magnet school). At this level, districts and states could gain information from cross-referencing entries of like-institutions and programs specifically supporting K-5 STEM education.

No data elements were found during the course of our research linked to Indicator 2: K-5 time allocations for science. That is, the language and data do not currently exist to monitor the existence of time on science in early grades (much less progress). The only information on time spent in school on science was through record-keeping about *high school* programs and courses (e.g., identifying how many periods of a school day were allotted to science, and regulations in some states, such as California for the specific time tied to subject matter). Information on Indicator 2 would greatly enhance district and elementary school level decision-making for scheduling, planning, allocation of personnel and supports, as well as coordination for programs with science specialists.

In California, many districts make use of science specialists as part of their elementary grades programs. However, science does not have equal standing with other disciplines in K-5 in terms of attention paid to learning time. Nationally, in grades K-5, there are mandates that involve documenting the minutes per week elementary school students engage in physical education and, in many states, similar documentation occurs for mathematics and reading. This difference across subject areas creates a climate of dissonance in elementary schools, where science becomes a third wheel, a subject that is only taught whenever there is time to squeeze it in; consistency and access to science learning are not equitable among grade levels or from classroom to classroom. Consequently, Indicator 3 emerges as an important metric for monitoring progress.

The opportunities to learn STEM are bound by, and can be roughly measured by, the time allocation given to the subject matter. In addition, Indicators 6, 7 and 8 impact student access to good quality instruction in science, as teachers without proper professional support may be less likely to teach science effectively (or at all) in the elementary classroom.

Community and Systemic Consequences

While data displays for the public continue to be important (e.g., through the Data Quality Campaign, 2019), rich and connected data that can be explored by and for professional decision-making has emerged as feasible and essential in the last decade. Addressing the NRC's 14 indicators is an important step. Progress in an indicator has repercussions for progress in others. Ultimately it will be important to understand those relationships. For example, what types of progress evidenced regionally in Indicator 7 may influence progress measured by systemic Indicators 12 and 13? It is likely that a teacher or leader who has participated in professional learning related to STEM will have knowledge that can inform professional community decisions (e.g., to seek funding that supports STEM-specific professional development and school programs). Data-driven decisions become a school-wide effort and all STEM subjects become integral in the dialogue among colleagues. Research already suggests this can foster the development of STEM education leaders.

Policies and planning for STEM instruction, materials, opportunities to learn, and teacher professional development are all interrelated. As teacher inductees enter teacher preparation programs, there is a synergy in place, which is driven by the common language in state standards and the expectations of standards for the teaching profession (e.g., the professional standards for the preparation of mathematics teachers, AMTE, 2017, and for science teachers, such as the K-8 Early Implementation Initiative, 2014-2020).

It will be valuable for schools, districts, and teacher educators to become familiar with the CEDS data dictionary. As more districts and states use/add/modify data elements specific to the STEM indicators, cross-referencing and networking through multiple databases will increase.

For classroom and school practitioners, Indicators 1 through 8 have immediate and significant value as sites for monitoring progress. The potential for greater coherence and professional discourse surrounding STEM decision-making would further enhance teacher pedagogical and content knowledge, teacher-decision-making voice, and response to accountability for, and ownership of, STEM school programs they may co-develop. Furthermore, driven by the convergence in the last decade of mathematics and science standards common across the nation (National Governors Association Center for Best Practices, Council of Chief State School Officers, 2010; NGSS Lead States, 2013), new curriculum adoptions and assessments are being put in place. Teacher expertise and insights are key for a successful transition and implementation of programs with rigorous standards. Some districts are already demonstrating this is possible. Ultimately, students, educators and communities at large all stand to gain from this synergy. Some indicators have had some documentation in mathematics, but science, computer science, engineering, and other STEM topics, particularly in grades K through 5, have not been given much attention in professional and policy conversation about STEM education. The time has come for this to change. The NRC's indicators and CEDS dictionary project offer an opportunity for local as well as national action.

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