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# Connecting Learning Opportunities in STEM Education: Ecosystem Collaborations across Schools, Museums, Libraries, Employers, and Communities

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**Abstract.** Education in Science, Technology, Engineering, and Mathematics (STEM) increasingly takes place across a wide range of environments. These cross-sector collaborations, referred to as ecosystems, advance STEM learning by combining theory and practice systematically across traditional education, a variety of out-of-school learning opportunities, and new approaches to workforce development. As of March 2018, there are 56 STEM learning ecosystems in North America involving more than 21 million students, 850,000 teachers and informal educators, 1,322 school districts, and over 1,200 out-of-school partnerships. Significant challenges emerge in efforts aimed at coordinating formative assessments and learning progressions for meaningful comparisons of the outcomes obtained within and between ecosystem niches. The conceptualization and implementation of STEM learning ecosystems have been informed by a sensitivity to and awareness of interdependent social relationships. This social ecology must now be complemented by a cognitive ecology that similarly facilitates more meaningful engagement with learning, for students, teachers, and larger communities. Promising directions for development are suggested by recent perspectives connecting Rasch's probabilistic models for measurement with possibilities for metrological traceability to unit standards. Characterizations of metrological networks as ecological systems emerging from recent work in the philosophy and history of science are of particular interest in this regard.

## 1. Introduction

Typical approaches to evaluating outcomes in education encounter difficult barriers to comparability when assessments appropriate in one environment are inaccessible or not applicable in another environment. In addition to problems of comparability across time and space, even in the context of common assessments, results are not as comparable across levels of aggregation as we typically assume they are. Philosophers, such as Whitehead and Russell, Wittgenstein, and Bateson, have long noted that everyday language almost unnoticeably incorporates variations in meaning across levels of complexity [1-3]. Measurement science and metrological traceability standards respect and negotiate the discontinuities associated with these levels of complexity in subtle ways that are still being brought to light [4-8]. Information infrastructures in most other areas of life, however, such as in education, health

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care, human resource management, etc., are not developed with the same capacities as metrology for dealing with these issues [9-11].

Metrological networks and shared languages are increasingly characterized in terms of cognitive ecologies in psychology, and in the history of science [5]. The embodiment of meaning in linguistic signs and symbols is similarly expressed in Bateson's terms as an ecology of mind [3]. These independent developments of ecological epistemologies are effectively integrated by Star and Ruhleder [9], who indicate how effective information infrastructures accommodate the need for flexibility and local concreteness without sacrificing continuity and navigability.

Successful results from creative new initiatives in education will likely remain elusive until outcome measurement information infrastructures incorporate the combinations of local flexibility and abstract comparability achieved in metrology [10,11]. Positive developments in this direction connect metrology and measurement science with Rasch's theory of measurement and results from applications of related probabilistic models [12-14] to the development of coherent information systems [15-17]. Figure 1 [from 10] illustrates the developmental, horizontal, and vertical dimensions of coherently coordinated classroom and accountability assessments.

## 2. STEM Learning Ecosystems

"The notion of ecologizing instruction refers to the process of placing abstract content back within its authentic contexts, referring to those contexts outside of schools in which the material serves a functional purpose" [18]. Questions that emerge in this context involve evaluating the effectiveness of ecologized instruction and the value obtained from the cross-sector partnerships. The challenges are how to compare individual learning relative to abstract content in schools and relative to the authentic functional purpose of the material. Additional questions emerge as to the quality of partnerships, their sustainability, and the alignment of learning outcomes across ecosystem niches.

STEM (Science, Technology, Engineering, and Mathematics) Learning Ecosystems (stemecosystems.org), for instance, provide the architecture for cross-sector learning, offering young people access to STEM-rich learning environments so they can develop important skills and engage with science, technology, engineering and math throughout the range of educational levels, from preschool through college (preK-16). Strong STEM Learning Ecosystems feature dynamic collaborations among schools, out-of-school programs, STEM expert institutions (such as museums, science centers, institutions of higher education, and STEM professional associations), the private sector, community-based organizations, youth, and families.

Rigorous, effective preK-16 instruction in STEM and learning beyond the classroom—in afterschool and summer programs, at home, in science centers, libraries and other places both virtual and physical—sparks young people's engagement, develops their knowledge, strengthens their persistence and nurtures their sense of identity and belonging in the STEM disciplines. Yet socioeconomic, linguistic, racial/ethnic, gender and other barriers too often prevent young people from accessing learning opportunities across all these settings. STEM Learning Ecosystems are designed to address these as-yet largely unmet needs, and so are intended to:

- Seek out and successfully engage young people historically under-represented in STEM to participate in high-quality, diverse and interconnected STEM learning experiences.
- Design and connect STEM learning opportunities to reflect the reality of young people's lives: learning not just in school but out-of-school, online, home and in daily life.
- Equip all STEM educators to understand the multiple learning contexts of young people and successfully lead them in active, collaborative and rigorous learning.
- Provide experiences in multiple settings that enable young people to build complex skills, including how to design, test and revise solutions to real-world problems, and to work collaboratively with adults and peers.
- Encourage young people to experience the joy of learning and the rewards of persistence through unhurried opportunities to tinker, experiment and explore areas of interest.

- Actively engage young people in science, engineering and mathematical practices, as detailed in the Next Generation Science Standards and other similar state standards for science education and the Common Core State Standards.
- Nurture young people's "STEM identity," or self-perception of competence in STEM. STEM Learning Ecosystems can do this by engaging them in challenging, relevant problem-solving on issues they care about; publicly recognizing them for their efforts; and helping their parents and guardians support their pursuit of and interest in STEM.
- Ensure parents and guardians have the capacity to support their children's STEM success by understanding the pathways to further STEM education and careers and accessing consistent guidance and resources.
- Assess what young people know and are able to do in diverse ways that are understood and respected across settings. New assessment strategies include use of such tools as digital badges, e-portfolios or other competency-based ways they can demonstrate mastery of skills and knowledge.
- Ensure young people have opportunities to meet and build mentoring relationships with STEM professionals from similar backgrounds who serve as role models. STEM Learning Ecosystems ensure that young people are taught, from an early age, about a range of STEM career possibilities.
- Connect preK-12 STEM learning, in and out-of-school, to post-secondary and STEM career opportunities.
- Match STEM learning pathways to the changing needs of STEM higher education and workforce.

There are currently 56 STEM learning ecosystems in North America, with 100 expected by the end of 2018. New initiatives are underway in Israel and other countries. In North America, more than 21 million students and 850,000 teachers and informal educators are involved in STEM learning in 1,322 school districts, and in over 1,200 out-of-school partnerships. In addition, over 4,350 philanthropic, business, and industry partners contribute funding, equipment, and learning environments to the ecosystems.

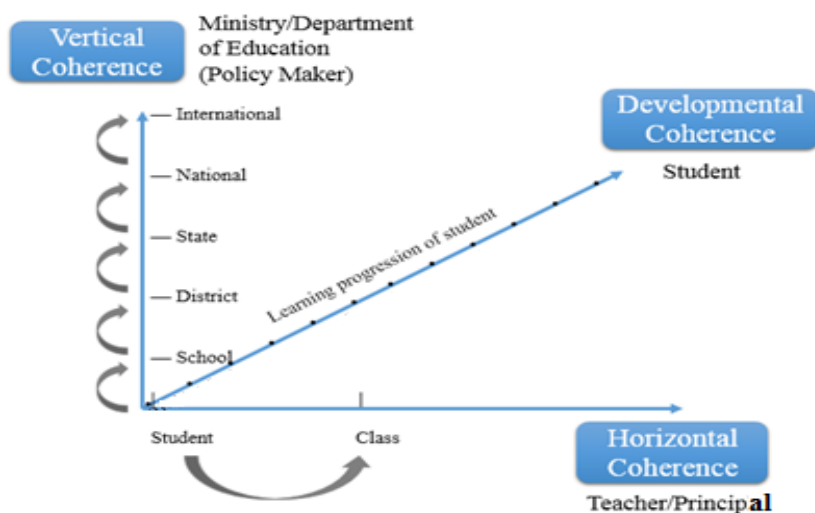


Figure 1. Assessment coherence types and relationships [10]

### 3. Evidence of success: The need for coherent measurement information infrastructures

Significant challenges emerge in efforts aimed at coordinating formative assessments and learning progressions for meaningful comparisons of the outcomes obtained within and between ecosystem niches. The conceptualization and implementation of STEM learning ecosystems have been informed by a sensitivity to and awareness of interdependent social relationships. This social ecology must now be complemented by a cognitive ecology that similarly facilitates more meaningful engagement with learning, for students, teachers, and larger communities.

Promising directions for development are suggested by recent perspectives connecting Rasch's probabilistic models for measurement with possibilities for metrological traceability to unit standards. Characterizations of metrological networks as ecological systems emerging from recent work in the philosophy and history of science are of particular interest in this regard. Research now in progress will seek to create the interconnected system of coherent assessments needed for advancing the educational mission of the STEM learning ecosystems.

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