Materials & Understanding for STEM Educators

MUSE

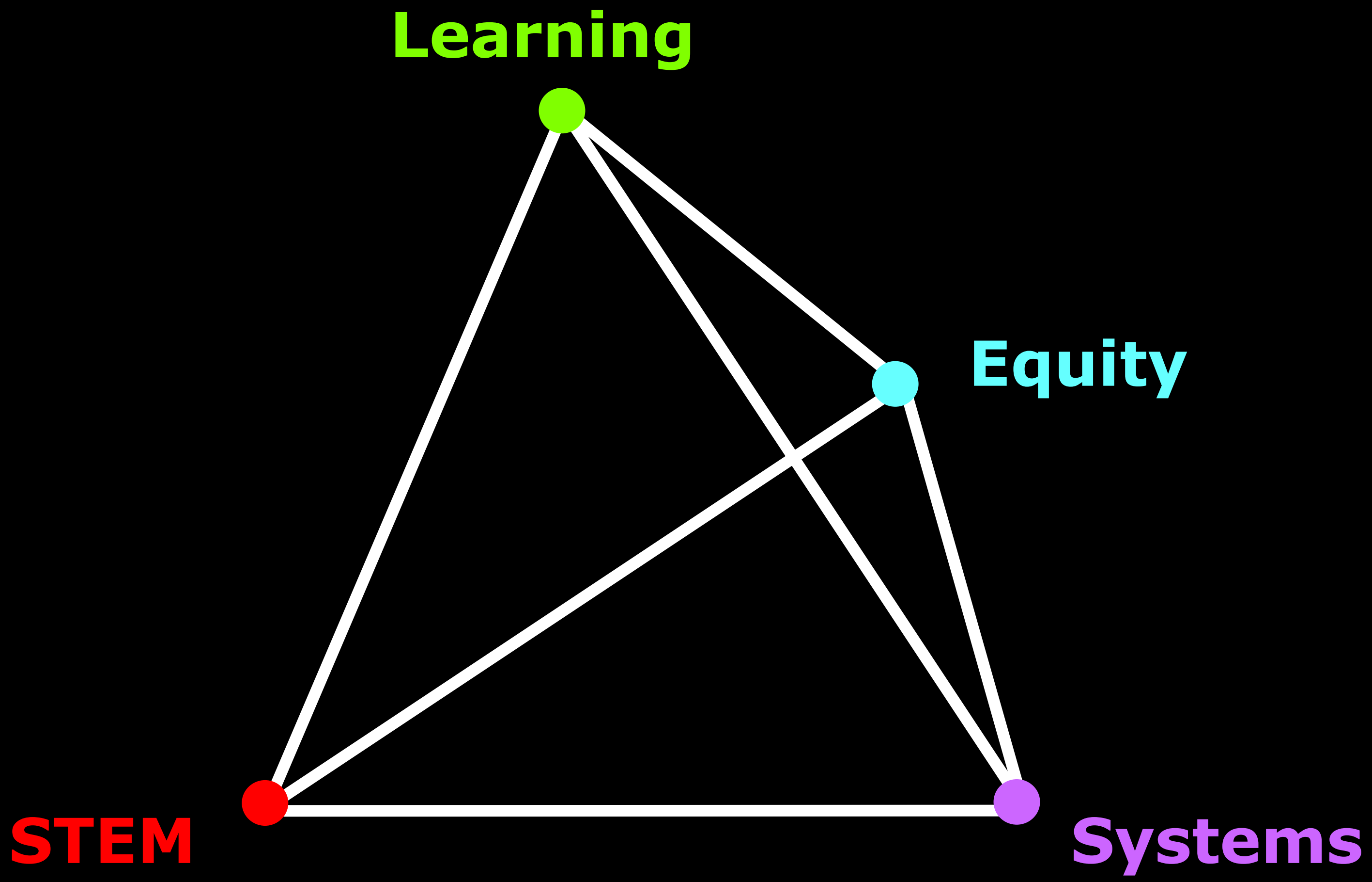
How an Informal Institution Supports Formal K-12 STEM Education

Liesl Chatman
Director of Professional Development
Science Museum of Minnesota

Supporting STEM: Professional Development

- Guiding Principles
- Nexus
- Science House
- Institutes

MUSE Guiding Principles



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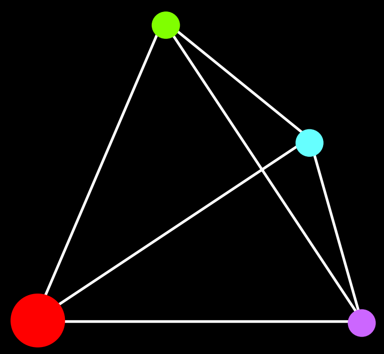

STEM

- STEM is an essential literacy for the 21st Century
- Assessment of high quality based on national standards in science (NCES, AAAS), mathematics (NCTM) and technology (ITEA)
- STEM Integration supports 8th Grade Algebra Readiness

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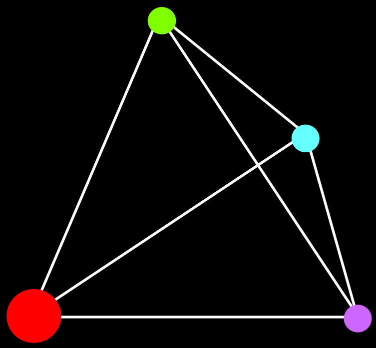
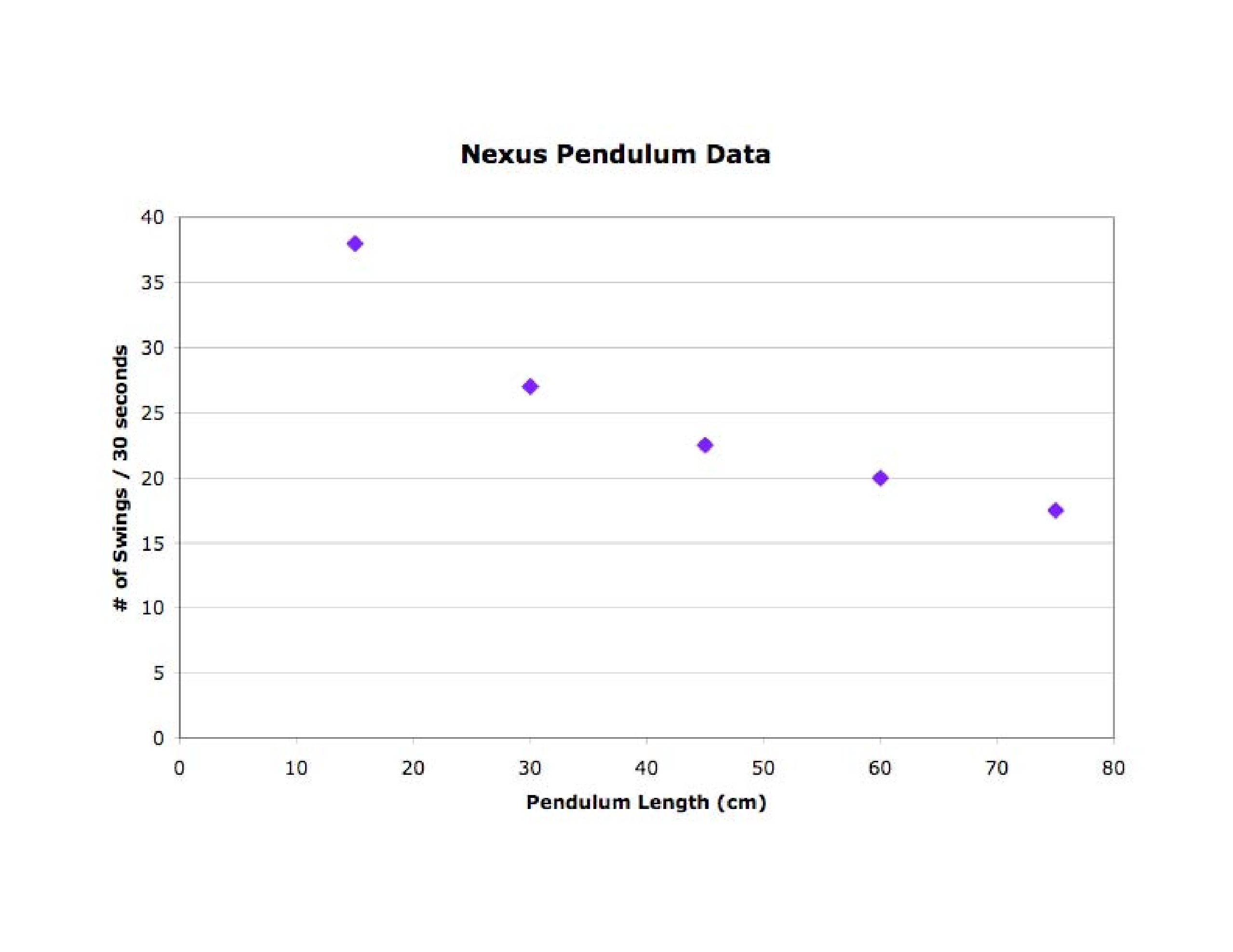


STEM

- Science: Understanding the Natural World
- Mathematics: Understanding Pattern and Abstraction
- Engineering: Using STEM outputs to solve problems
- Technology: Tools extend human capacity and are the products of science, math, and engineering

STEM Integration Example: Pendulum Behavior



STEM Integration Example: Pendulum Behavior

Based on the data for the number of swings in 30 seconds with a pendulum length of 15 to 75 centimeters, can you use algebraic modeling to predict the number of swings in 30 seconds using a length of 200 centimeters?

STEM Integration Example: Pendulum Behavior

$$y = \frac{c}{\sqrt{x}}$$

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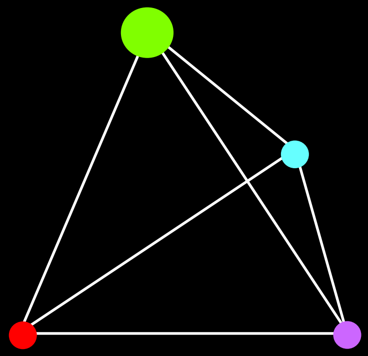

Learning

- Incremental Theory of Intelligence
- Learning as the arbiter of success
- Acknowledge that both children and adults are learning

Self-Theories About Intelligence

Fixed Intelligence and the Fixed Mindset

Intelligence is a fixed trait. We all have a certain amount of it and that's that. A Fixed Mindset results in worrying about how much intelligence you have and how to demonstrate that you have enough.

Performance Goals

Winning positive judgments of competence and avoiding negative ones – wanting to look smart and avoid looking dumb. Accomplished by playing it safe and avoiding mistakes or taking on a harder task that you're pretty sure you'll do well at. The best tasks for the purposes of looking smart are ones that are hard for others but not for you.

The Helpless Response

A view that once failure occurs, the situation is out of your control and nothing can be done. It includes the following reactions: denigration of your intelligence, plunging expectations, negative emotions, lower persistence, blaming, and deteriorating performance.

Self-Theories About Intelligence

Incremental Intelligence and the Growth Mindset

Intelligence is not a fixed trait that one simply possesses, but something everyone can cultivate through learning. Intelligence is increased through efforts. A Growth Mindset results in learners wanting to learn.

Learning Goals

These goals are about increasing your competence. It reflects a desire to learn new skills, master new tasks, or understand new things – a desire to get smarter.

The Mastery Response

A hardy response to failure that allows you to remain focused on achieving mastery in spite of present difficulty. It includes: self-instruction or self-monitoring designed to aid performance, optimism, positive mood, and persistence.

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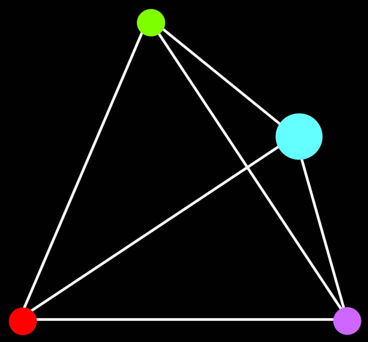


Equity

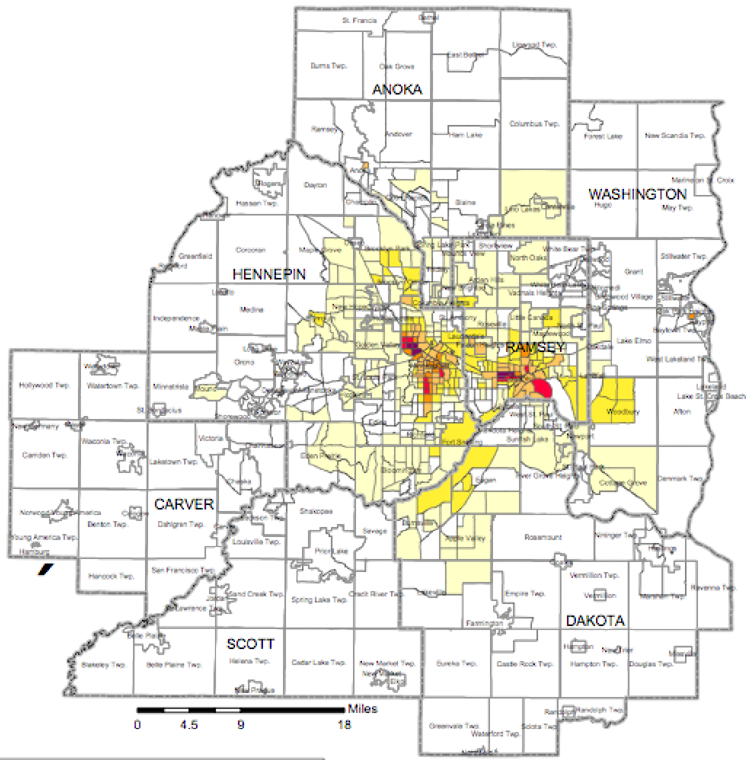
- A workforce imperative for Minnesota

1980

Twin Cities Metropolitan Area

Racial and Hispanic* Minority Population Distribution, 1980

as a percent of total census tract population



Percent of total census tract:

- Less than 2.5%**
- 2.5% - 4.9%
- 5% - 9.9%
- 10% - 24.9%
- 25% - 49.9%
- 50% - 74.9%
- 75% - 94%

1990 census tracts

MCD boundary

County boundary

Source: U.S. Census Bureau.

Metropolitan Council

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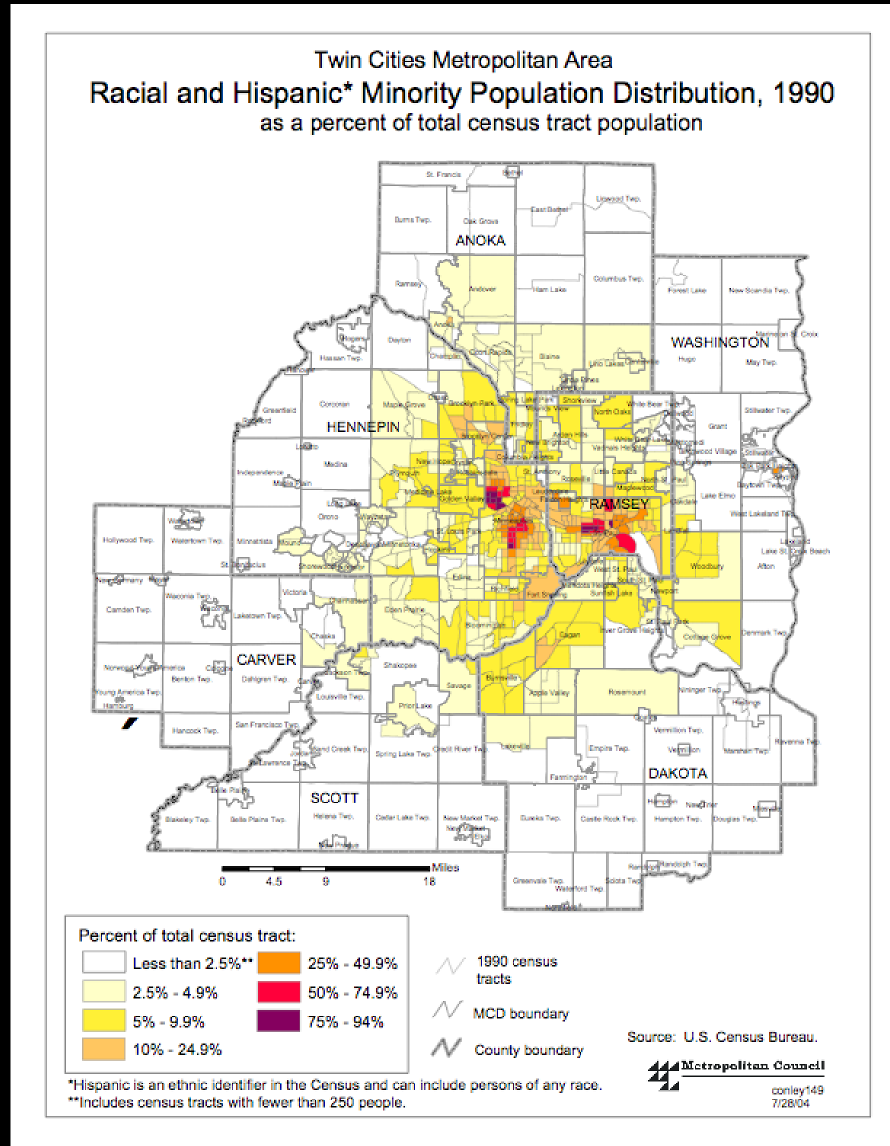
*Hispanic is an ethnic identifier in the Census and can include persons of any race.
**Includes census tracts with fewer than 250 people.

1990



Twin Cities Metropolitan Area
Racial and Hispanic* Minority Population Distribution, 1990
as a percent of total census tract population
ANOKA
WASHINGTON
HENNEPIN
RAMSEY
CARVER
SCOTT
DAKOTA
Miles
0
4.5
9
18
Percent of total census tract:
Less than 2.5%**
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1990 census tracts
MCD boundary
County boundary
Source: U.S. Census Bureau.
Metropolitan Council
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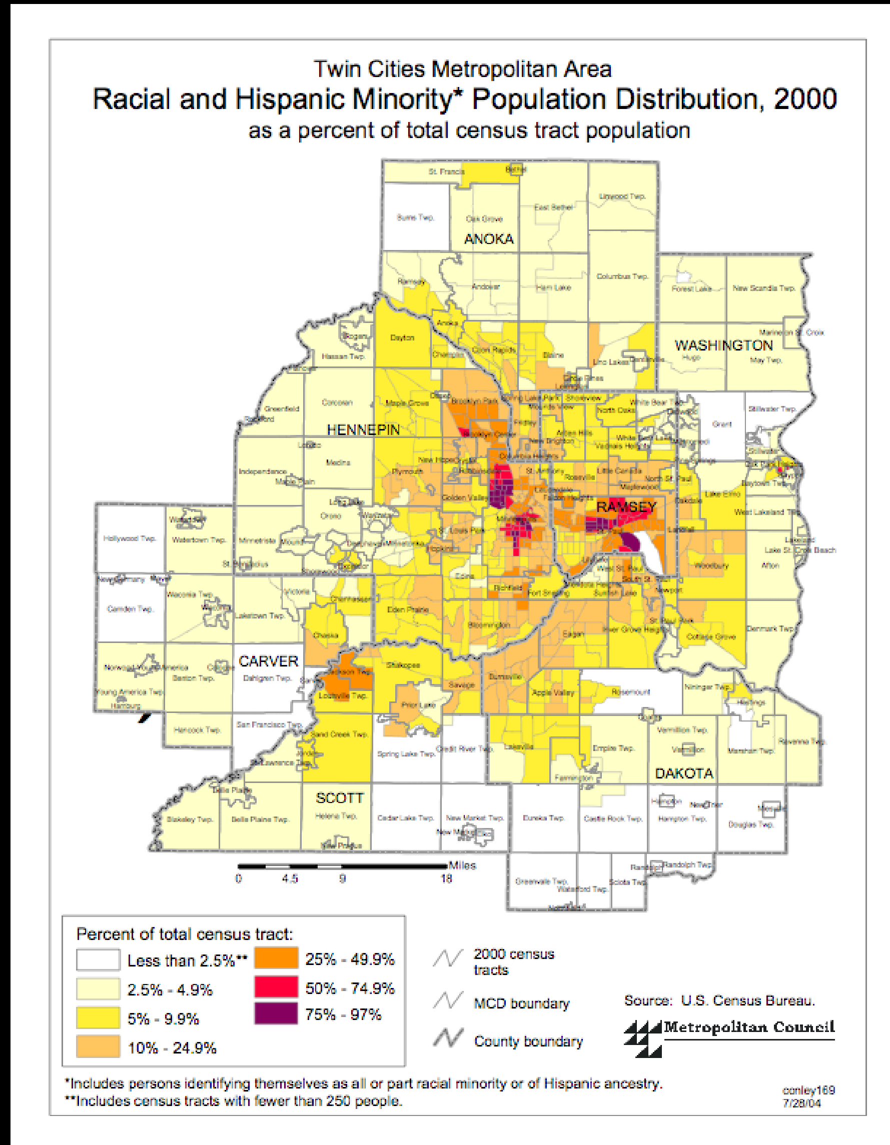
2000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2000 census tracts
MCD boundary
County boundary
Source: U.S. Census Bureau.
Metropolitan Council
*Includes persons identifying themselves as all or part racial minority or of Hispanic ancestry.
**Includes census tracts with fewer than 250 people.
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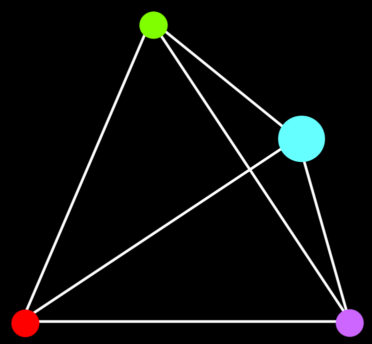

Equity

- A workforce imperative for Minnesota
- Close the Achievement Gaps between White Students and Students of Color
- Increase Cultural Relevance in curriculum
- Promote Cultural Competence in instruction
- Expand socio-political perspectives

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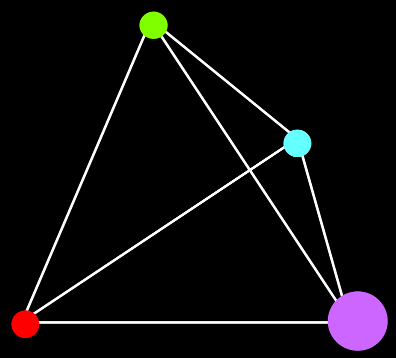


Systems

- Vertical articulation of concepts across grade levels
- Coherency across schools and within STEM
- Local context and resources

MUSE Guiding Principles

NATURE OF MATHEMATICS (2AB)

The universe is made up of galaxies, mountains, organisms, vehicles, and a wide variety of other things, each seemingly unique. Moreover, these things interact with one another in all sorts of ways, often violently but sometimes with great subtlety. But thanks to mathematics, people are able to think about the world of objects and events and to communicate those thoughts in ways that reveal unity and order. Mathematics is a universal language for describing patterns and relationships, both about abstractions and about objects and events in the real world. The results of theoretical and applied mathematics often influence one another, contributing to a better understanding of the world.

The map is organized around three strands—*study of patterns, universal language for describing things,* and *connections to science and technology.* They reflect key understandings students are expected to develop about mathematics as the study of patterns that involves the interplay of theory and application and that both draws on and contributes to science and technology.

In the elementary grades, the focus is on the use of quantities and shapes to describe real-world objects and events. Middle-school benchmarks emphasize the role of mathematics in representing change over time, negative quantities, and data sets. High-school benchmarks emphasize the role of mathematics in modeling real-world events and technological designs. Connections are made to benchmarks describing the contribution of computers to these mathematical activities.

In addition to other maps in this chapter, the map draws upon and contributes to maps in Chapter 9: THE MATHEMATICAL WORLD, in Chapter 11: COMMON THEMES, and in Chapter 12: HABITS OF MIND.

The use of mathematical models is a special case of how mathematics contributes to science and technology. The progression of understanding about mathematical models is laid out in the MATHEMATICAL MODELS map in *Atlas 1*. The use of mathematical models in science and technology is developed in greater depth in the MODELS map.

NOTES

Many specific ideas about the uses of mathematics (such as using shapes and numbers to describe objects and events or using graphs to help make predictions about phenomena), contribute to the 6-8 benchmark "Mathematics is helpful in almost every kind of human endeavor…." More abstract ideas about and uses of mathematics (such as those involving negative numbers, measures of central tendency, and mathematical modeling) contribute to the 9-12 benchmark "Mathematics provides a precise language…" and to a more in-depth understanding of the utility of mathematics in all fields of human endeavor, not just in science and technology.

Most mathematical theories have applications, and much work in mathematics is motivated by seeking answers to applied problems, often in science and technology. This connection is depicted by the arrows linking 9-12 benchmarks "Developments in mathematics often stimulate…" and "Developments in science or technology often stimulate…" to the 9-12 benchmark "Theories and applications in mathematical work…"

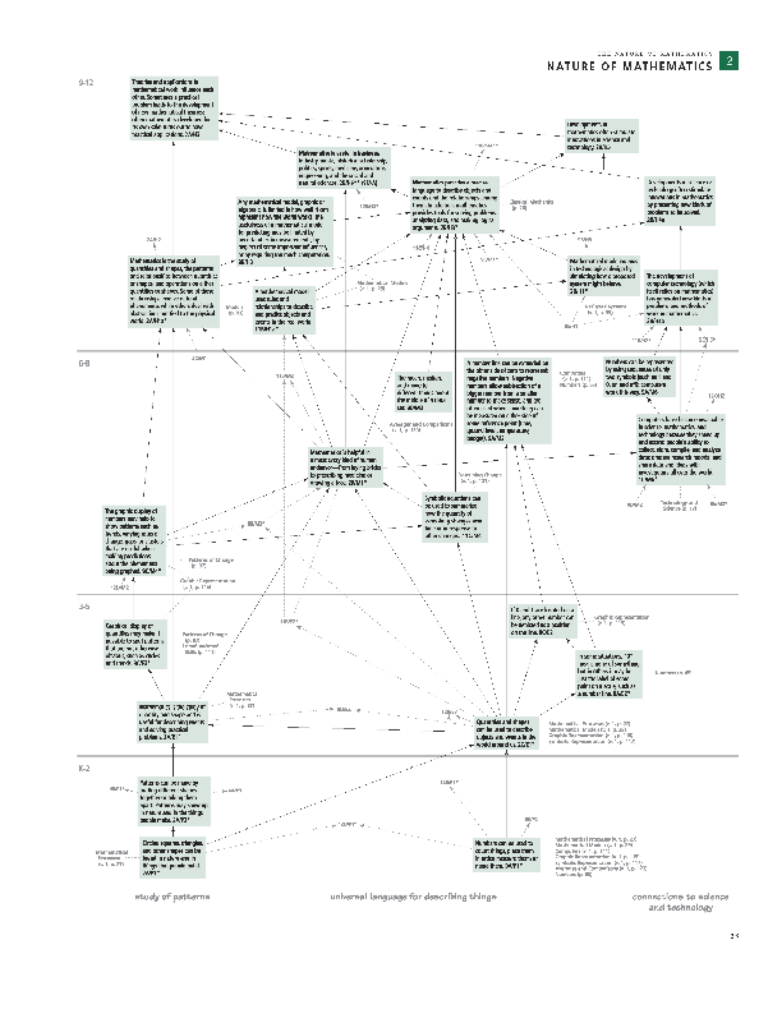
RESEARCH IN *BENCHMARKS*

Early reviews of the research (e.g., McLeod, 1992; Schoenfeld, 1992; Thompson, 1992) support continuing studies of beliefs, attitudes, and values about the nature of mathematics. For descriptions of international research programs, see the volume edited by Leder, Pehkonen, and Toerner (2002), and the special issue on affect published by *Educational Studies in Mathematics* (e.g., Zan, Brown, Evans, & Hannula, 2006). For a more comprehensive review of recent literature, with an emphasis on teacher beliefs, see Philipp (in press). Data on student beliefs and attitudes are also a component of large-scale studies, such as the National Assessment of Educational Progress and the Third International Mathematics and Science Study (see, e.g., Silver & Kenney, 2000). Investigations of students' beliefs about the nature of mathematics are illuminated by Schoenfeld (1992) and summarized in a report from the National Research Council (Kilpatrick, Swafford, & Findell, 2001). These studies examined difficulties arising from students' beliefs about the nature of mathematical problem solving and from their perceptions of the role of memorization in learning mathematics and of mathematics as rule-oriented versus process-oriented or as a static versus a dynamic discipline. There has been less emphasis on students' understanding of the relationships between mathematics, science, and technology or to the nature of mathematical inquiry as a modeling process.

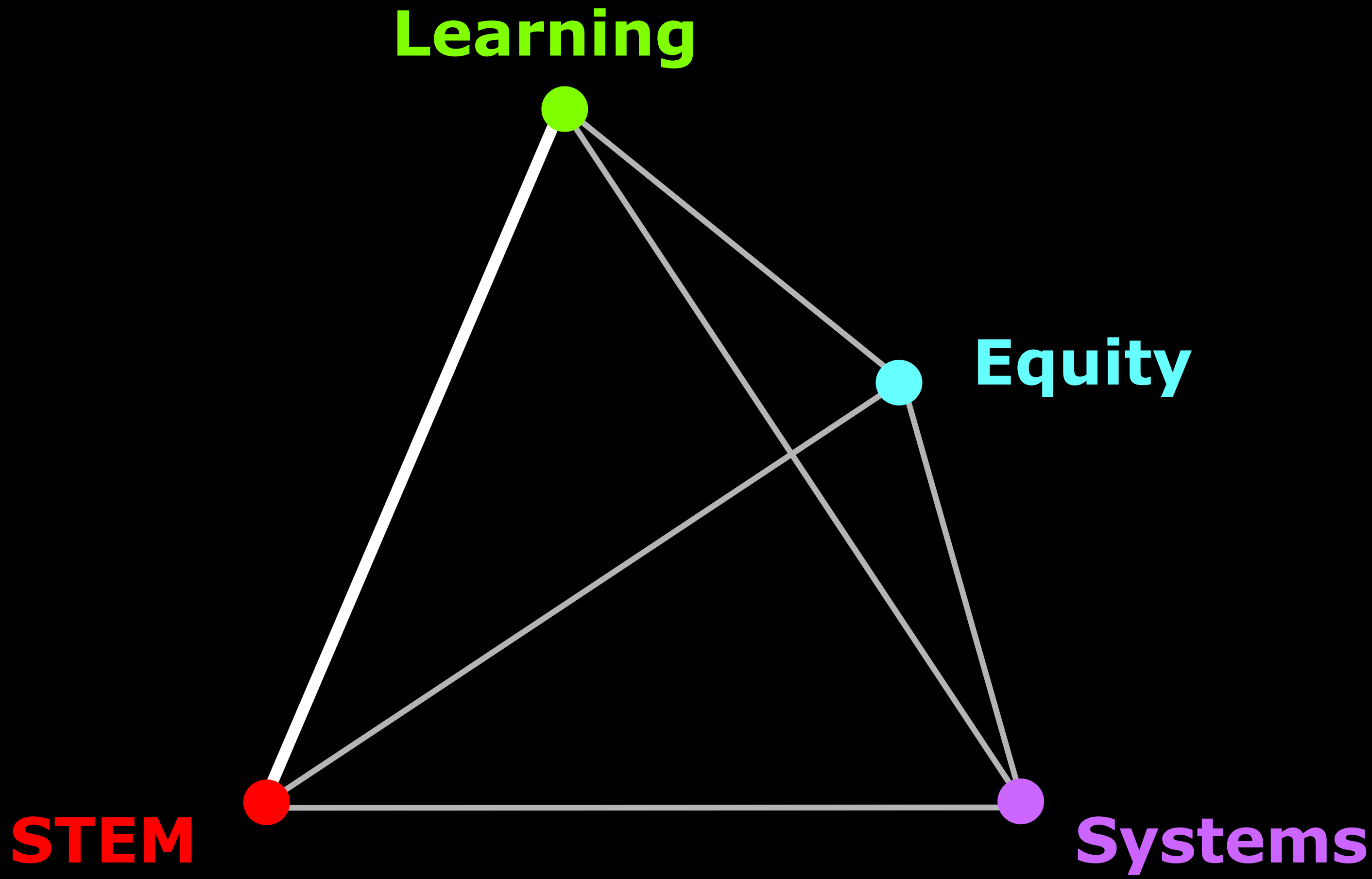
Research on student understanding of early algebra ideas, such as patterns and relationships, has received increased attention. Early studies suggested students have difficulty connecting mathematical expressions, sentences, and sequences that share common structural patterns, often focusing instead on incidental similarities or differences (Ericksen, 1991). Evidence suggests that these difficulties can be ameliorated by introducing early algebra ideas in the elementary grades (Carpenter, Franke, & Levi, 2003).

Research on the integration of new technologies into mathematics instruction continues to advance and is summarized in a National Research Council report (Kilpatrick, Swafford, & Findell, 2001). Kieran and Sfard (1999) discuss how students develop stronger conceptual knowledge of equations through graphing, and there is evidence that students can use technological tools to improve problem-solving even when their algebraic skills are limited (Huntley, Rasmussen, Villarubi, Sangtong, & Fey, 2000). Survey data suggest that middle- and high-school students think that mathematics has practical, everyday uses and that mathematics is more important for society than for them personally (Brown et al., 1988).

Typical student beliefs about mathematical inquiry that limit students' mathematical behavior (Schoenfeld, 1985, 2006) include the following: There is only one correct way to solve any mathematics problem and only one correct answer; mathematics is done by individuals in isolation; mathematical problems can be solved quickly or not at all and their solutions do not have to make sense; and formal proof is irrelevant to processes of discovery and invention (Schoenfeld, 1985, 1989a, 1989b). Research is needed to assess when and how students can understand that mathematical inquiry is a cycle in which ideas are represented abstractly, abstractions are manipulated, and results are tested against the original ideas. We must also learn at what age students can begin to represent something by a symbol or expression, and what standards students use to judge when solutions to mathematical problems are useful or adequate.



MUSE Guiding Principles



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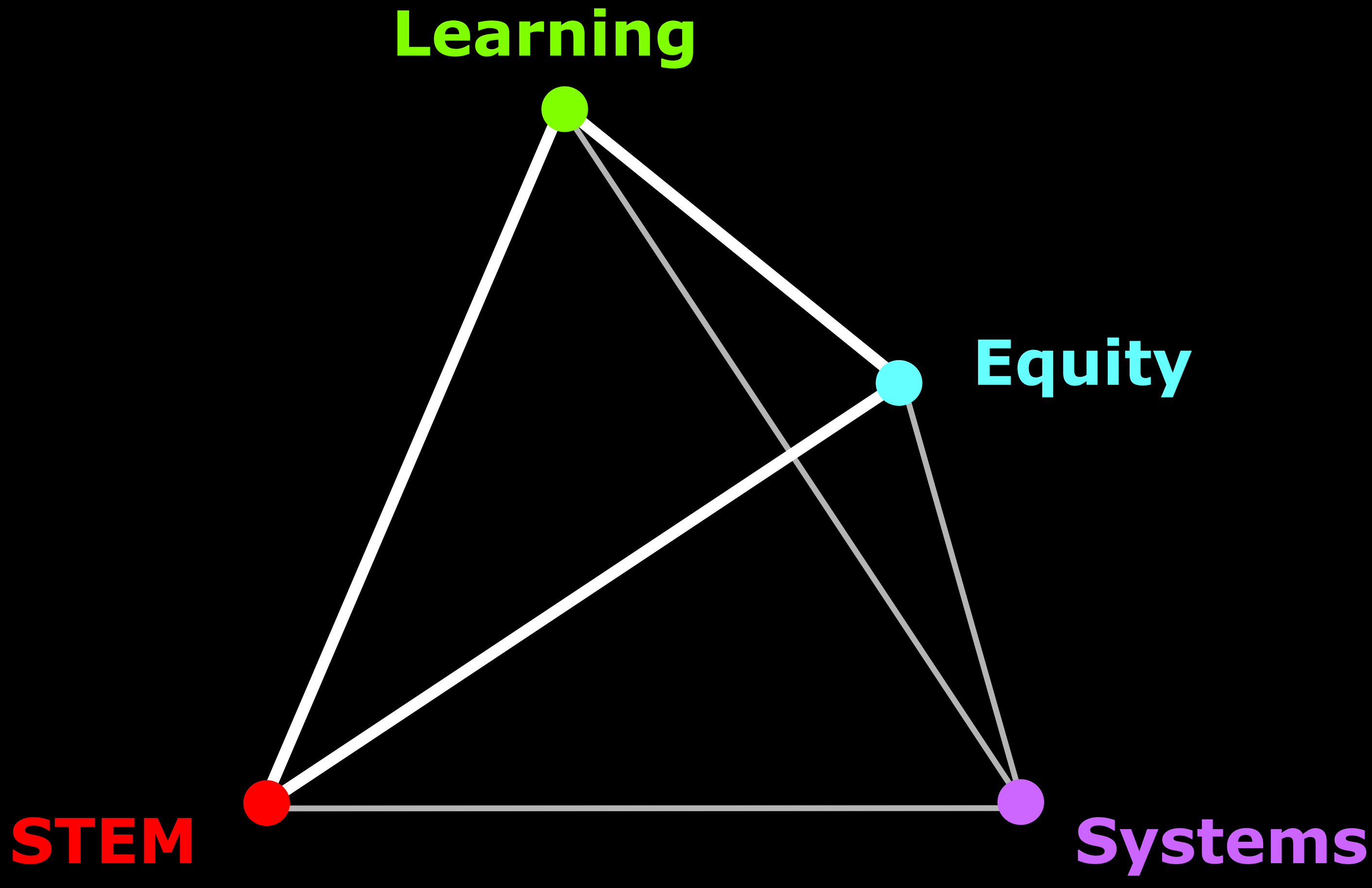

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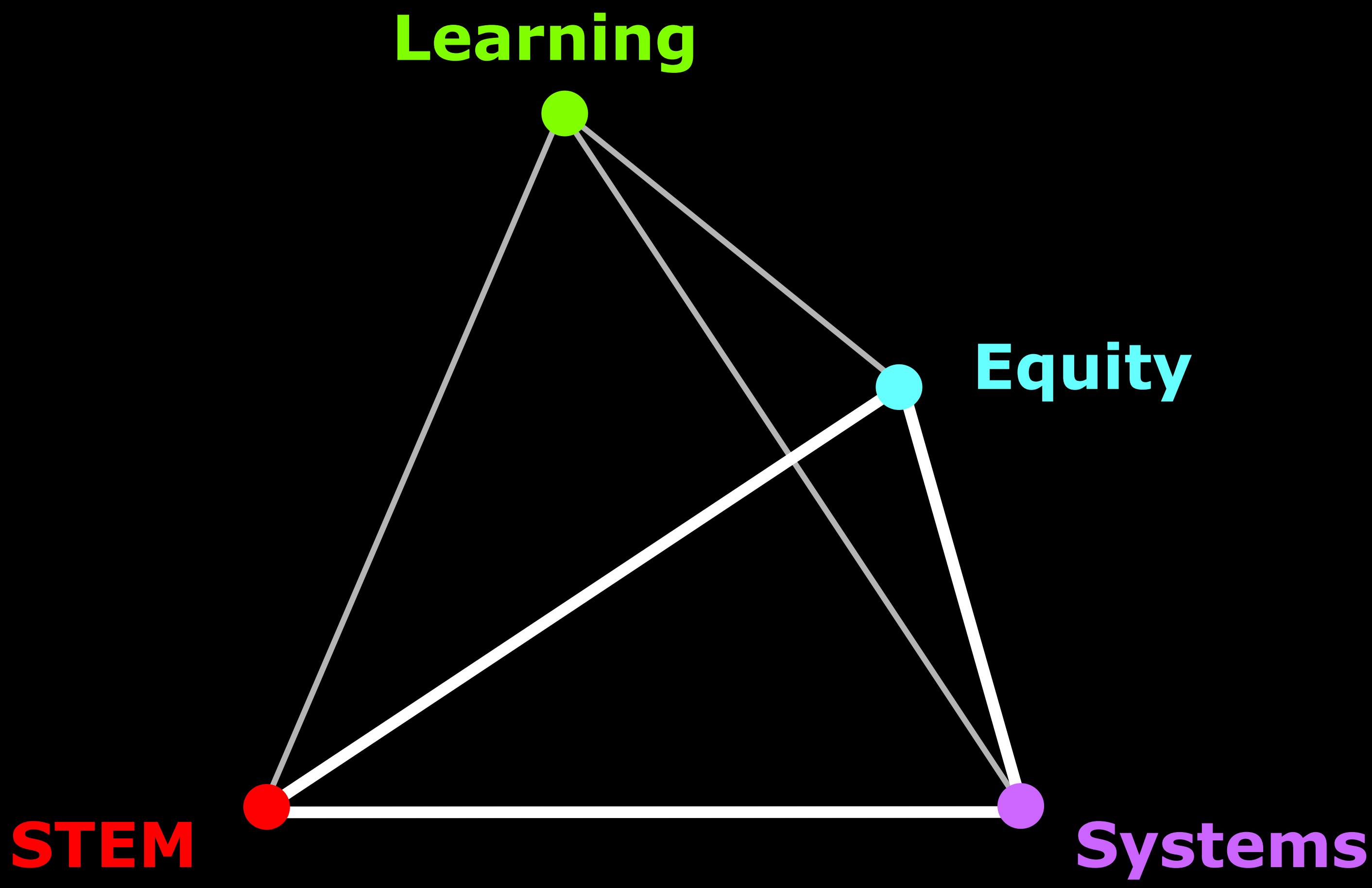

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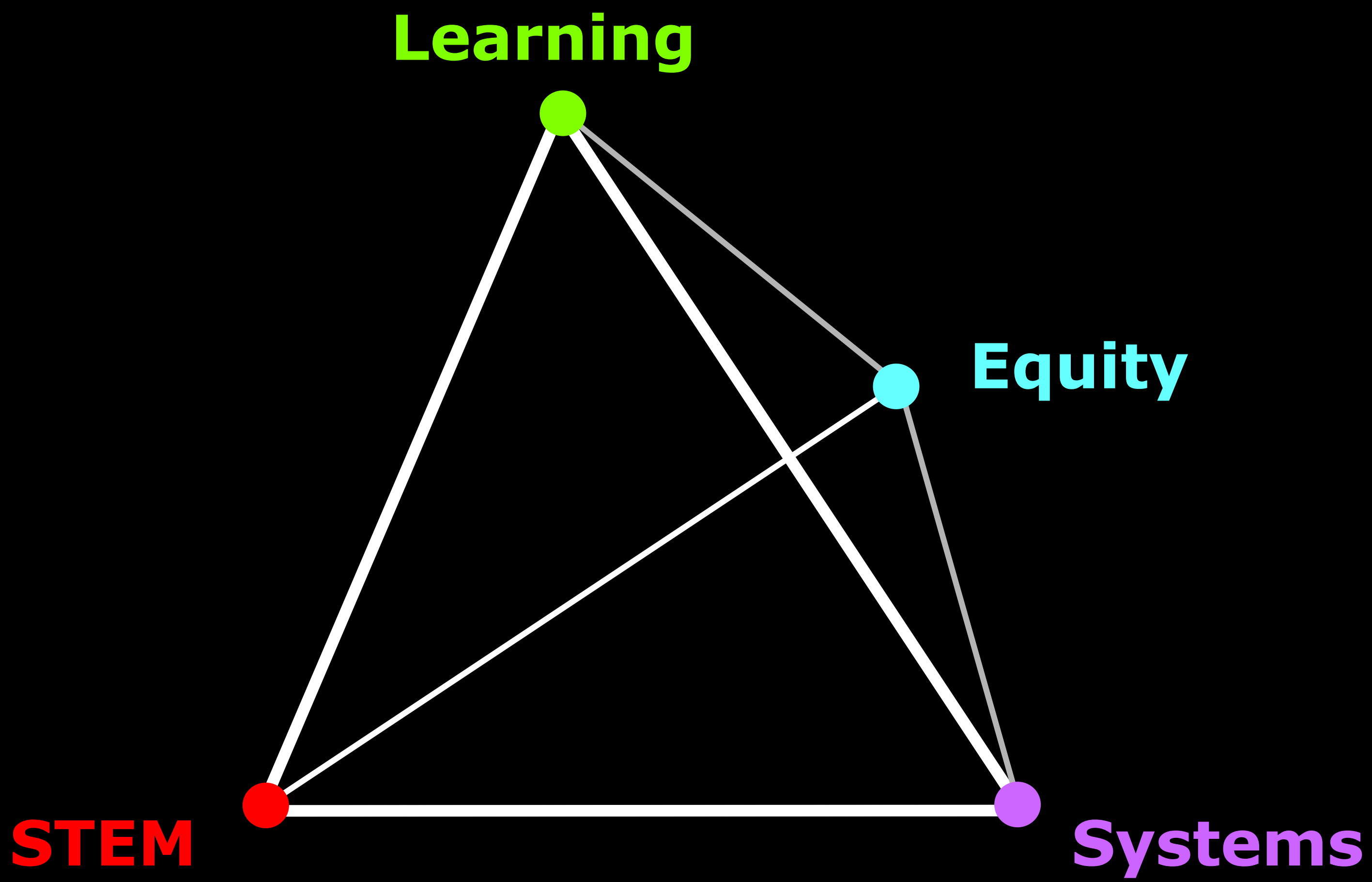

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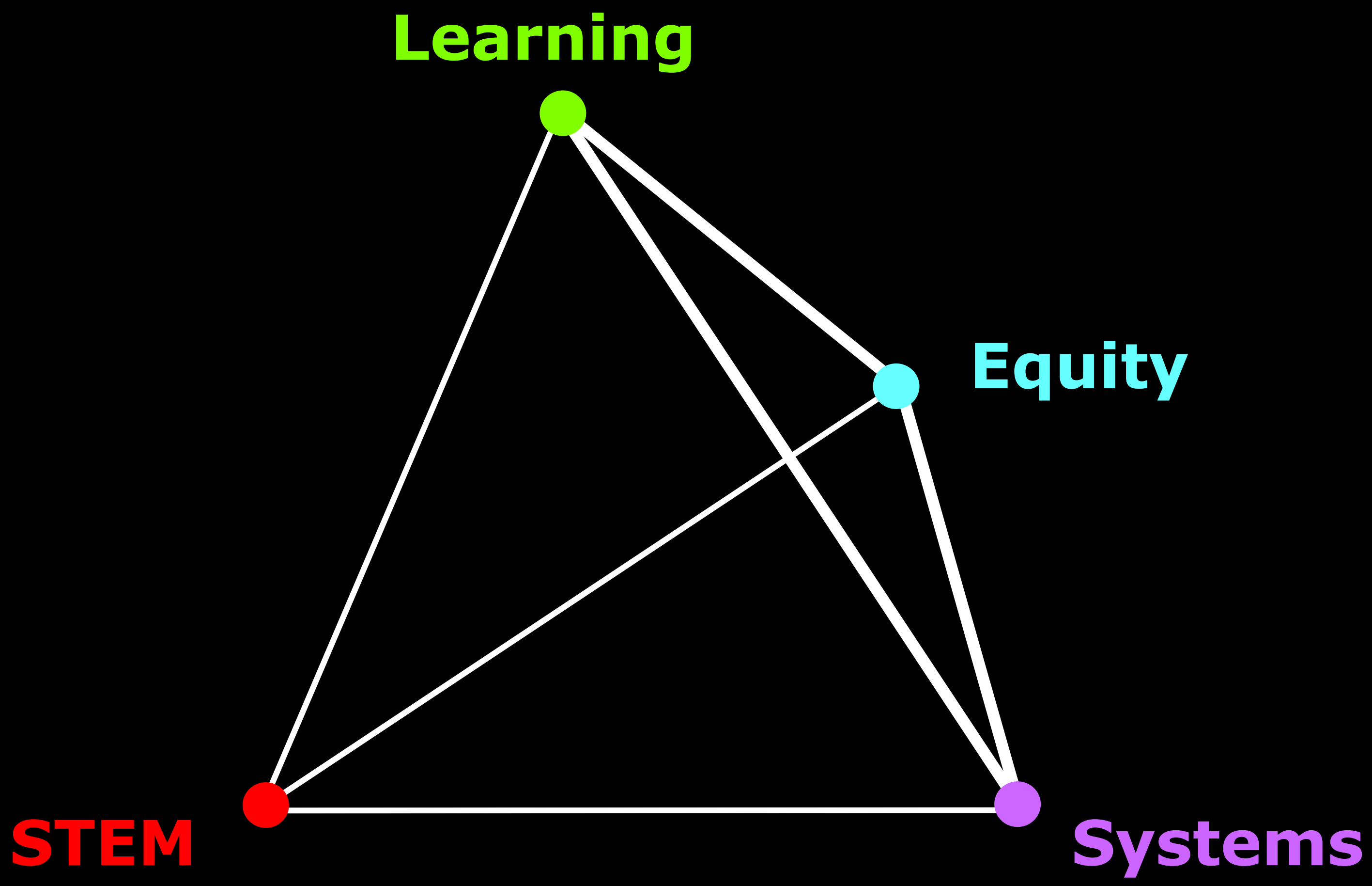

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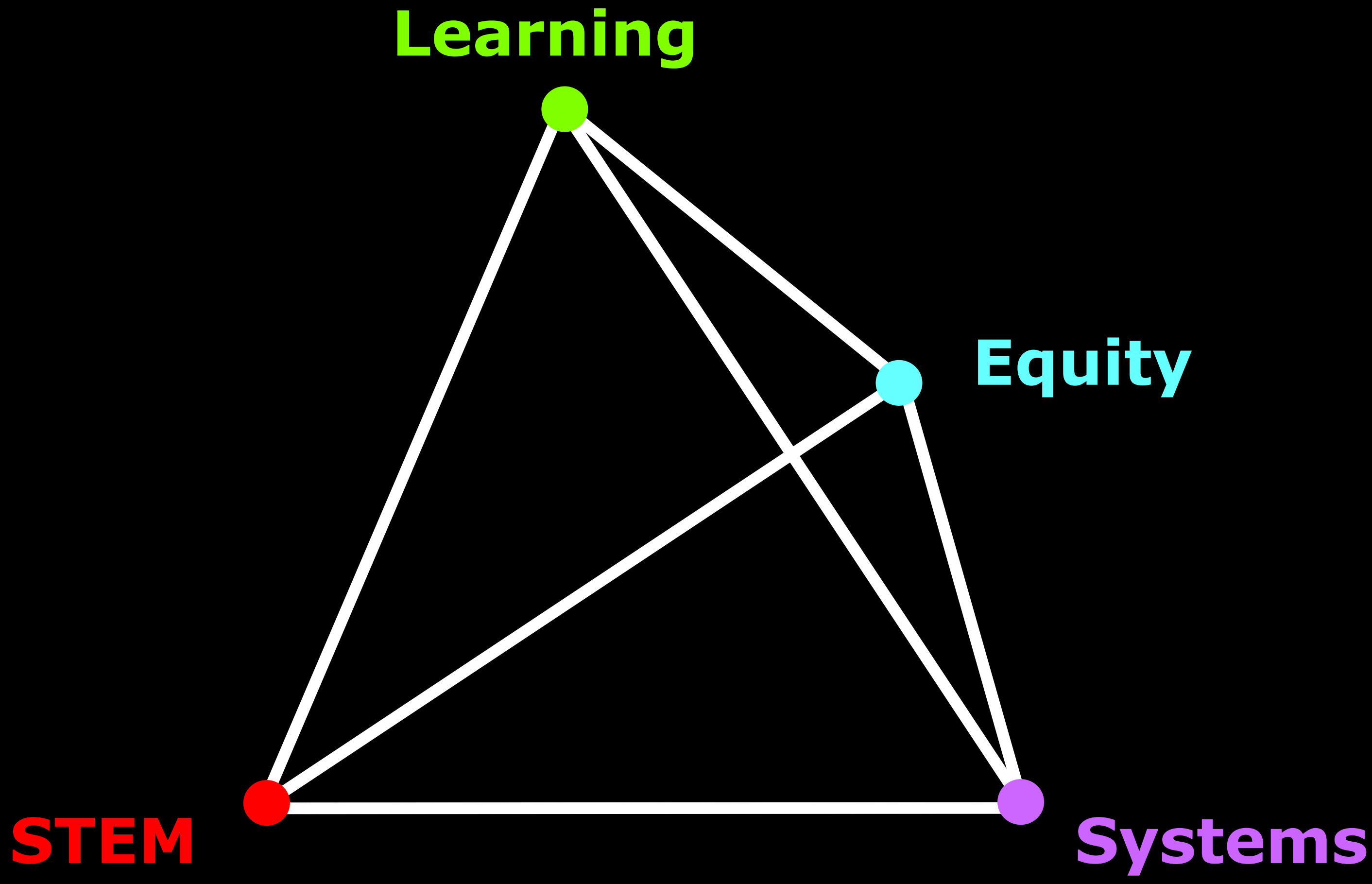


MUSE Guiding Principles in action through PROGRAMS

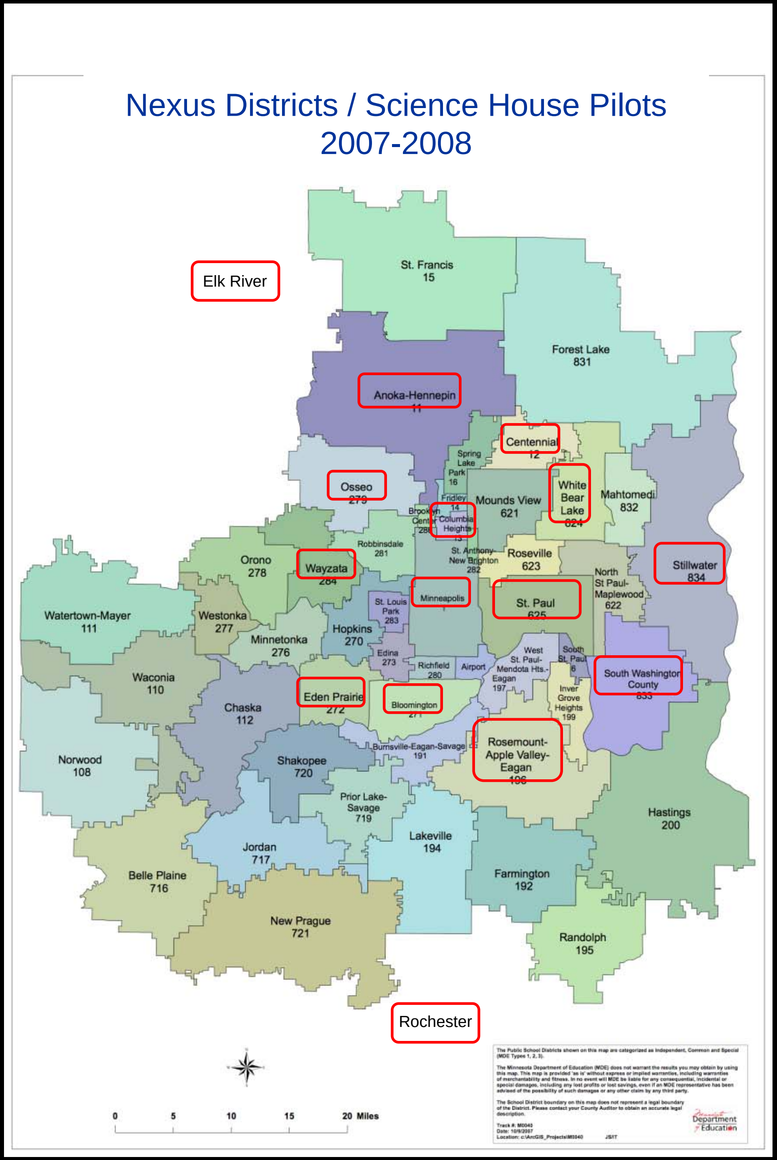
Nexus

- Professional development for district-level STEM leaders
- 17 districts / 45 participants
- Jointly funded by the Medtronic Foundation and the State
- Guiding Principles
- Networked Community

Nexus Districts / Science House Pilots

(% increase in URM 1990-2005)

Anoka Hennepin (314%)
Bloomington (224%)
Centennial (146%)
Columbia Heights (374%)
District 196 (326%)
Eden Prairie (446%)
Elk River (451%)
Hopkins (274%)
Minneapolis (44%)
Mounds View (124%)
Osseo (397%)
Rochester (254%)
So. Washington County (344%)
St. Paul (102%)
Stillwater (90%)
Wayzata (271%)
White Bear Lake (218%)



Science House

Primary Functions

- Networking and Community Building
- Informal and Formal Consultation
- Program Support
- Curricular Materials

Membership

- Membership by District
- Annual fees based on district size & distance from museum
- Charter & private schools eligible
- Colleges & universities eligible
- Unlimited use by teachers in member districts
- Customized Services

Professional Development

- Summer Institutes
- Partner with the state-wide MnSCU System
- Pilots with Bemidji, Mankato, Metropolitan State, St.Cloud, Southwest State, Winona
- District & School teams
- Collaboration with the *Teacher Academies in Math & Science* (TAMS)
- Museum School Outreach

From 30,000 Feet

- MUSE is about translating related fields of research into STEM-specific practice
  - Guiding Principles
  - Integrating the Guiding Principles
- The MUSE approach is novel
  - Making an investment in Minnesota
  - Creating a national model
- The museum is uniquely positioned to undertake this effort
  - Creative, nimble, rigorous
  - Respected and neutral convener

SMM Professional Development Team

Liesl Chatman, Professional Development Director
Larry Thomas, School Outreach Director
Marjorie Bullitt Bequette, Project Lead
Erin Villegas Strauss, Project Lead
Nils C. Halker II, Specialist
Molly Leifeld, Specialist
Travis O. Sandland, Specialist
Sarah Carter, Science House Librarian
Quanda Arch, Coordinator
Amanda Faz, Coordinator
Julie Marckel, Administrative Assistant