Making Math Work

A Pedagogic and Professional Development Strategy for Success

James R. Stone III, Director
Today’s Agenda

- Where we started: the context and the science
- Where we are: technical assistance
- Where we are going: ?
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The Holy Trinity of HS Reform

- **Engagement** – attending school and completing (graduating) high school
- **Achievement** – academic (and technical) course taking; grades, test scores
- **Transition** – to postsecondary education without the need for remediation; and to the workplace
Engagement
% of 9th Graders who complete High School

Source: One-Third of a Nation (ETS, 2005)
National Graduation Rates 1998 and 2001 The problem of engagement
Figure 6.4
Average Credits Earned by High Schools Students, by Type of Course Work: 1982–2000


1Includes courses such as art, music, and driver’s education.
When do they leave?

Month at which dropout occurred

From Plank, forthcoming
Why they leave

CTE and School Engagement

![Graph showing the relationship between CTE/Academic course-taking ratio and probability of dropout. The graph includes three lines representing different scenarios: Tests & GPA 1 s.d. below grand means, Tests & GPA at grand means, and Tests & GPA 1 s.d. above grand means. The x-axis represents the CTE/Academic course-taking ratio, ranging from 0 to 1.2, while the y-axis represents the probability of dropout, ranging from 0 to 0.6.]
Graduation: School and CTE Effects

From Castellano, Stringfield & Stone, Forthcoming
CTE Structures and Pedagogies and Completing HS

- Students in or Career Majors are 16% more likely to graduate from high school.
- Students in Tech Prep are 30% more likely to complete high school.
- Students who participated in specific STW activities are 18% more likely to complete high school.

Stone & Aliaga, in press
Achievement
The Challenge: Improve the academic skills of youth

Reading Scores – 17 year old

NAEP Scores cited in Stringfield, Castellano, & Stone, 2001
More Problems:
Science Performance

17 Year Olds

A Nation At Risk

Scale Score

Year


305 296 290 283 288 290 294 294 296 295
Here is the Problem:
Math Performance of American Youth

NAEP Scores for 17 Year olds

- 1973: 304
- 1975: 300
- 1977: 299
- 1981: 302
- 1985: 305
- 1989: 307
- 1991: 306
- 1995: 307
- 1997: 308
- 2001: 307
- 2004: 307
The number of 17-year-old students taking advanced math classes has also increased -- with 17 percent studying calculus and 53 percent studying second-year algebra -- it is unclear why that trend has not resulted in higher average math scores over all.

http://nces.ed.gov/nationsreportcard/ltt/results2004/
12th Grade Math Scores 2005

Scale score

Average score

Percentile score

150
105
127
151
174
194

0
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240

Basic

Proficient
One solution?

Be born to smarter parents!
Taking more math is no guarantee

- 43% of ACT-tested Class of 2005\(^1\) who earned A or B grades in Algebra II did not meet ACT College Readiness Benchmarks in math (75% chance of earning a C or better; 50% chance of earning a B or better in college math)

- 25% who took more than 3 years of math did not meet Benchmarks in math (NOTE: these data are only for those who took the ACT tests)

A better solution

Math-in-CTE

A study to test the possibility that enhancing the embedded mathematics in Technical Education coursework will build skills in this critical academic area without reducing technical skill development.
Why Focus on CTE

- CTE provides a math-rich context
- CTE curriculum/pedagogies do not systematically emphasize math skill development
Key Questions of the Study

- Does enhancing the CTE curriculum with math increase math skills of CTE students?
- Can we infuse enough math into CTE curricula to meaningfully enhance the academic skills of CTE participants (Perkins III Core Indicator)
- Without reducing technical skill development
- What works?
Study Design

- Random assignment of teachers to experimental or control condition
- Five simultaneous study replications
- Three measures of math skills (applied, traditional, college placement)
- Multi-method: quantitative and qualitative
- Focused on naturally occurring math (embedded in curriculum)
- Test a model of Curriculum Integration
- Intense focus on Fidelity of Treatment
Measuring Math & Technical Skill Achievement

- Global math assessments
- Technical skill or occupational knowledge assessment
- General, grade level tests (Terra Nova, AccuPlacer, WorkKeys)
- NOCTI, AYES, MarkED
What we tested:

1. Professional Development
   - Summer PD (5 days) – Mapping and lesson creation
   - Late fall PD (2-3 days) - Lesson creation
   - Early Spring PD (2-3 days) – Lesson creation
   - On-going direct and indirect math support

2. The Math Enhancement Process
   (The 7 Element Pedagogic Model)
Math-in-CTE Professional Development
“Year-at-a-Glance”

July-Aug
5 Days Professional Development
Teach Lessons

Sept-Nov
2 Days Professional Development
Teach Lessons

Dec-Feb
2 Days Professional Development
Teach Lessons

Mar-May

June
I Day Wrap-up Celebration

On-going monitoring of teacher progress
Professional Development

Curriculum Mapping
Curriculum Maps

- Begin with CTE Content
- Create “map” for the school year
- Align map with planned curriculum for the year (scope & sequence)
## Connecting to Standards

<table>
<thead>
<tr>
<th>Agricultural Mechanics Curriculum</th>
<th>Mathematics Content Standards</th>
<th>PASS Standards</th>
<th>NCTM Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Determining sprayer nozzle size given flow rate and speed</td>
<td>Problem solving involving cross-sectional area, volume, and related rates</td>
<td>PASS Process Standard 1: Problem Solving</td>
<td>NCTM Problem Solving Standard for Grades 9-12</td>
</tr>
<tr>
<td>Determine pipe size and water flow rates for a water pump</td>
<td>Problem solving involving cross-sectional area, volume, and related rates</td>
<td></td>
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<tr>
<td>Determine amount of paint needed to paint a given surface (calculate surface area, etc)</td>
<td>Problem solving involving surface area, ratio and proportions</td>
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<tr>
<td>Determine the concrete reinforcements and spacing needed when building a concrete platform or structure</td>
<td>Problem solving involving cross-sectional area, volume, and related rates</td>
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</tr>
</tbody>
</table>
## Scope & Sequence

<table>
<thead>
<tr>
<th>TIME</th>
<th>CTE CONCEPT</th>
<th>MATH CONCEPT</th>
<th>MATH-IN-CTE LESSON</th>
<th>MATH STANDARD</th>
<th>MATH PARTNER MEETING DATE</th>
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</thead>
<tbody>
<tr>
<td>WEEK 1</td>
<td>Marketing and DECA Orientation</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
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<tr>
<td>Aug. 17</td>
<td></td>
<td></td>
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<tr>
<td>WEEK 2</td>
<td>DECA Orientation</td>
<td>General Overview of the Math-in-CTE Project</td>
<td>NA</td>
<td>NA</td>
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<td>Aug. 23</td>
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<tr>
<td>WEEK 3</td>
<td>Sales Unit</td>
<td>Introduction to the 7 Math Concepts</td>
<td>Consent Forms, Student Survey, and Math Pre Test</td>
<td>NA</td>
<td>Sept. 2</td>
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<tr>
<td>Aug. 30</td>
<td>(Officer Elections)</td>
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<tr>
<td>WEEK 4</td>
<td>Sales Unit</td>
<td>Ratio/Percentages</td>
<td>#1 – To Market, To Market; Lesson #25</td>
<td>Standards 1, 6</td>
<td>Sept. 9</td>
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<td>Sept. 7</td>
<td>(TSLP begins)</td>
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<tr>
<td>WEEK 5</td>
<td>Sales Unit</td>
<td>Graphing/Predictions</td>
<td>#4 - What Product to Sell</td>
<td>Standards 1, 2, 3, 5, 6</td>
<td>Sept. 16</td>
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<td>Sept. 13</td>
<td></td>
<td>Algebraic Expressions, Pattern Recognition, Functions, Data Representation</td>
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</table>
What we tested:
The Seven Elements Pedagogy

1. Introduce the CTE lesson
2. Assess students’ math awareness
3. Work through the embedded example
4. Work through related, contextual examples
5. Work through traditional math examples
6. Students demonstrate understanding
7. Formal assessment
Common Vocabulary

- This is a bore of a piston
- This is also the diameter of a circle
Common Vocabulary

- This is the stroke of a piston
- This would also be considered the height of a cylinder (relatively speaking)
Piston Displacement vs. Volume

Equivalent formulas

\[ PD = \frac{B^2 S \pi}{4} \]

\[ V = \pi r^2 h \]
<table>
<thead>
<tr>
<th>Math Concept</th>
<th>Site A</th>
<th>Site B</th>
<th>Site C</th>
<th>Site D</th>
<th>Site E</th>
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<tr>
<td>Number and Number Relations</td>
<td>8</td>
<td>4</td>
<td>4</td>
<td>10</td>
<td>2</td>
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<td>Computation and Numerical Estimation</td>
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<td>7</td>
<td>6</td>
<td>12</td>
<td>12</td>
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<td>Operation Concepts</td>
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<td>1</td>
<td>0</td>
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<tr>
<td>Measurement</td>
<td>5</td>
<td>7</td>
<td>3</td>
<td>0</td>
<td>12</td>
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<td>Geometry and Spatial Sense</td>
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<td>1</td>
<td>0</td>
<td>0</td>
<td>2</td>
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<tr>
<td>Data Analysis, Statistics and Probability</td>
<td>11</td>
<td>9</td>
<td>4</td>
<td>1</td>
<td>4</td>
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<tr>
<td>Patterns, Functions, Algebra</td>
<td>7</td>
<td>1</td>
<td>3</td>
<td>5</td>
<td>2</td>
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<tr>
<td>Trigonometry</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
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<tr>
<td>Problem Solving and Reasoning</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Communication</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
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</tbody>
</table>
What we found: All CTEx vs All CTEc
Post test % correct controlling for pre-test
Effect size tells us what the average percentile standing of the average treated (or experimental-blue curve) participant relative to the average untreated (or control) participant.
Effect size (Cohen’s $d$)

All Classes
- Terra Nova ($d=.55$)
- Accuplacer ($d=.42$)

By Site
- Site A – WorkKeys ($d=2.8$)
- Site B – Terra Nova ($d=.69$)
- Site C – Accuplacer ($d=.85$)
- Site E – Terra Nova ($d=.64$)
- Site F – AccuPlacer ($d=.39$)

Percentile “Shift”
From 50th to:
- 71st
- 67th
- 99th
- 76th
- 81st
- 74th
- 66th

What we found: Magnitude of effect

Carnegie Learning Corporation
Cognitive Tutor
Algebra I

d= .22
Does Enhancing Math in CTE Affect Technical Skill Development?
No difference in four sites; experimental students scored significantly higher in one site.
Time invested in Math Enhancements

- Average of 18.55 hours across all sites devoted to math enhanced lessons (not just math but math in the context of CTE)

- Assume a 180 days in a school year; one hour per class per day

- Average CTE class time investment = 10.3%
Replicating the Math-in-CTE Model:

Core Principles

A. Develop and sustain a community of practice
B. Begin with the CTE curriculum and not with the math curriculum
C. Understand math as essential workplace skill
D. Maximize the math in CTE curricula
E. CTE teachers are teachers of “math-in-CTE” NOT math teachers
The *Professional Development Paradigm in Practice*

### Old Model
- A *box* of curriculum
- Short term “training”
- Little or no support after the “sage on the stage” goes away
- Replicable by individual teachers (assumed)

### New Model
- Process not an event
- Built on communities of practice
- On-going support – the learning curve
- Requires teams of committed teachers working together over time
Power of the New Professional Development Model

Math in CTE Use 1 Year Later

- Total Surprise!
- Old Model PD
- New Model PD
Perkins IV: Required Activity

- Professional Development
  - **Cannot** be “1-day or short-term”
  - Currency
  - Integration/rigor
  - Meet levels of performance
  - Coordinated with title II of ESEA
Math-in-CTE in Context

- **Disconnected**
  - Algebra 1
  - Traditional academic class (e.g. Algebra 1)

- **Coordinated**
  - Academies
  - CTE & Academic teachers coordinate around themes (e.g. ‘health’)

- **Context Based**
  - Integrated math
  - Occupation is the context for delivery of traditional academics (Related or applied math)

- **Contextual**
  - NRC Model
  - Academics emerge from occupational content
Remaining Issues

- Class impact vs. program impact
- Tipping point (how much math)
- Other academic areas (e.g., science, literacy)
- Pre-service options
- Potential impact of other approaches (e.g., context based)
Final thoughts: Math-in-CTE

- A powerful, evidence based strategy for improving math skills of students;
- A way but not THE way to help high school students master math;
- Not a substitute for traditional math courses;
- Lab for mastering what many students learn but don’t understand;
- Strategy for getting past Calvin…
Math-in-CTE in Your State/District

Teacher Recruitment
Spring 2007

NRC Workshop
Summer 2007

Contract
Nov 1 2007

Teacher Support/PD
School year 2007-08

Final Set of Materials
June 2008
Required for success

- State/District Leadership working with...
- CTE content experts working with ...
- A critical mass of teachers focused on ...
- Helping students achieve!
- Questions?
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