Texas NSA Project
Numeracy Skills Needed for QR Success in General Chemistry
Deborah Walker, PhD & Diana Mason, PhD, ACSF

The National Numeracy Network
11:30-12:00, Wells Hall A118
October 13, 2018

Abstract
Success in first-semester general chemistry, a known ‘high-risk’ course, is being studied as a continuing research endeavor by the NSA Texas team to evaluate college-ready students’ number sense ability needed for course success. Results indicate that lacking basic arithmetical skills (Cohen’s $d = 2.22$) may be hampering students’ numeracy ability more than the highly touted algebraic skill set (Cohen’s $d = 0.206$) usually associated with success in CHEM 1. Informed decisions indicate that basic arithmetic skills have deteriorated or at a minimum become dormant over years possibly due to dependency on e-calculating devices. Without foundational arithmetic skills, advancing QL/QR abilities may be limited. Presented will be the results of a two-year study of $n = 3,265$ students from eight higher education institutions in Texas based on data gathered from the MUST (arithmetic) and DAT (algebra) diagnostic instruments.

Unified Learning Model (ULM)
(Shell et al., 2010)

- Memory –
  – Working: where connections are made
  – Long-term: learned information
- Motivation –
  – Directs WM towards learning
- Prior knowledge –
  – Determines ease, speed, and efficiency of processing
- Engagement (meaningful!) –
  – Shared responsibility

Shared Responsibility

Where is the breakdown?

Shared Responsibility

What can QR/QL understanding do for Meaningful Engagement?
### 30-years of SAT: Texas v. USA
(Max score = 1600)

<table>
<thead>
<tr>
<th>Year</th>
<th>Texas</th>
<th>USA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1967</td>
<td>1,000</td>
<td>800</td>
</tr>
<tr>
<td>1970</td>
<td>1,100</td>
<td>900</td>
</tr>
<tr>
<td>1973</td>
<td>1,200</td>
<td>1,000</td>
</tr>
<tr>
<td>1976</td>
<td>1,300</td>
<td>1,100</td>
</tr>
<tr>
<td>1979</td>
<td>1,400</td>
<td>1,200</td>
</tr>
<tr>
<td>1982</td>
<td>1,500</td>
<td>1,300</td>
</tr>
<tr>
<td>1985</td>
<td>1,600</td>
<td>1,400</td>
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Math = 1600 Total (up 58 points)

### 2017 U.S. SAT:
- Evidence-Based Reading and Writing: 533
- Math: 527
- Total: 1,060 (up 58 points)

### 2017 SAT:
- Texas: 1,020 composite (up 76 points)

### Proficiency
“A real phenomenon we’re now seeing is that we have more and more students with a diploma, but we also know — look at test scores over the last few years — we’re not graduating more students who are proficient.”


### NSA Team (2017-2019)
(All with IRB Approval)
- Diana Mason, UNT (retired)
- Collaborating researchers
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  - Anton Dubrovskiy, UHCL Assistant Professor
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*MSI = 50%+ URMs

**Goal:** Get all 37 Texas Public Universities on board!

### Protocol
- Research plan
  - Year 1 (Pilot): Effect(s) of calculator (n = 2,117)
    - MUST
  - Year 2: Effect(s) of automaticity (n = 3,266)
    - MUST
  - DAT
  - Year 3: Effect(s) of automaticity (n = 643+)
    - MUST
  - OR
    - Non-cognitive: Higher Education Expectations
- Drop instrument with smaller effect size
- Add new instruments each iteration
AY 1: Pilot Study

MUST (no calculator) & Course grade
\[ r = .451 \text{ (WITHOUT)} \quad \text{and} \quad r = .402 \text{ (WITH)} \]

0.00 10.00 20.00 30.00 40.00 50.00 60.00 70.00 80.00 90.00 100.00

Mean (WITHOUT) 7.36/16 = 46.0%
Mean (WITH) = 12.19/16 = 76.2%

Are Students Dependent on Calculators?

Positive slope without calculators; negative slope with!

AY 2: Prior Knowledge Focus

High School Chemistry

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<th>DAT (SD)</th>
<th>PreCal +</th>
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<td>AP/IB</td>
<td>240</td>
<td>84.6 (11.3)</td>
<td>12.2 (4.6)</td>
<td>16.7 (3.2)</td>
<td>166/240 = 69.2%</td>
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<tr>
<td>Pre-AP</td>
<td>536</td>
<td>79.8 (12.9)</td>
<td>10.4 (4.8)</td>
<td>15.7 (3.4)</td>
<td>357/536 = 66.6%</td>
</tr>
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<td>Regular</td>
<td>276</td>
<td>76.3 (12.8)</td>
<td>8.9 (4.9)</td>
<td>14.7 (3.6)</td>
<td>138/276 = 50.0%</td>
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<tr>
<td>None</td>
<td>12</td>
<td>71.2 (13.8)</td>
<td>6.2 (3.5)</td>
<td>13.1 (5.2)</td>
<td>6/12 = 50.0%</td>
</tr>
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Majority of students (276 + 395/1,073 = 62.5%) currently are enrolled in pre-cal or higher (groups A and B) and have a B average.
Fall 2017 MUST vs. Course Average

\[ y = 1.5036x + 62.198 \]
\[ R^2 = 0.9321 \]

Most-missed Example Problems (< 30% correct)

- Division with exponential notation:
  - \( \frac{9.0 \times 10^{-1}}{2.0 \times 10^{-2}} \)
  - \( \frac{10^9 \times 10^{-10}}{} \)
- Logs: Determine the base-10 log of: 1000 = \( \_ \_ \_ \) and 0.001 = \( \_ \_ \_ \)
- Power of 10 square root: \( \sqrt{64 \times 10^{-12}} \)
- Division by 0: If \( A = B \), evaluate \( \frac{A}{A-B} \)

None of 20 questions > 70% correct!

*New question for fall 2017

MUST (by institution)

DAT: Algebra Skills

Slope: \( m = 1.39 \)

DAT (by institution)

Letter Grades

Identify the potential D/F students at the beginning of semester (or before) and provide them with the HPs needed to improve their math-sense!
Prior Knowledge

High School Chemistry Background (Fall 2017)

Correlations & Effect Sizes

Course average (SD) = 76.75 (15.56)

Correlation ($r$): MUST:DAT = 0.700

Effect Size DAT: Course Avg = .206 [small]
indicating 50% chance of predicting average from DAT (algebra skills)

Effect Size MUST: Course Avg = 2.22 [huge]
indicating that there is a 80% chance (or greater) of predicting course average from MUST (arithmetic skills)

Predictability of MUST Ranges (Fall 2017)

Average Student Profile

Quantitative Reasoning (Fall 2018)

AY 3: QR Introduction

Preparation
• Graduated from TX High School
• Took Pre-AP Chemistry
• First-time in course (Avg = 76%)
• STEM major
• Co-enrolled in Pre-Cal or higher
• Plans to take Chem II
• Parents and grandparents have some college
• Does not work

Nonacademic

• Graduated from TX High School
• Took Pre-AP Chemistry
• First-time in course (Avg = 76%)
• STEM major
• Co-enrolled in Pre-Cal or higher
• Plans to take Chem II
• Parents and grandparents have some college
• Does not work

Quantitative Reasoning (Fall 2018)

$N = 643$; correlation between MUST and QR = 0.658 (a little lower than with the DAT, $r = 0.700$); mean on MUST = 6.69; mean on QR = 12.09
Most Missed QR Arithmetic

0.8% means:

a. 8 out of 100  
b. 0.8  
c. 8.0  
d. 0.08  
e. \frac{0.8}{100}

Most Missed QR Word Problems

Let \( U_L = \frac{r}{1-x} \). Solve this equation for \( U_L \) in terms of \( U_d \) and \( r \).

\[
\begin{align*}
U_L &= \frac{r}{1-x} \\
U_d &= \frac{r - x}{x} \\
L &= \frac{r}{x} \\
K &= \frac{r - x}{x} \\
X &= \frac{r - x}{x} \\
\end{align*}
\]

In a certain company there are 3 times as many men working as women. What is the fraction of employees that are female?

a. \( \frac{3}{4} \)  
b. \( \frac{3}{10} \)  
c. \( \frac{3}{2} \)  
d. \( \frac{3}{4} \)  

Near Most Missed QR with Image

The attached gauge shows the power output of a small motor up to one-half horsepower (hp). Express the power output shown by the gauge in horsepower (hp), simplifying any fractions. Assume that the sections are evenly spaced.

\[
\begin{align*}
0 \text{ hp} & \quad \% \text{ hp} \\
a: \frac{2}{9} & \quad b: \frac{3}{4} & \quad c: \frac{3}{8} & \quad \frac{3}{16} & \quad e: \frac{4}{3}
\end{align*}
\]

MUST vs QR: Institution

<table>
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<tr>
<th>Institution Type</th>
<th>n</th>
<th>MUST</th>
<th>QR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small, HISI</td>
<td>71</td>
<td>2.23</td>
<td>9.75</td>
</tr>
<tr>
<td>Middle, Pub</td>
<td>76</td>
<td>5.26</td>
<td>10.20</td>
</tr>
<tr>
<td>Large, HISI</td>
<td>79</td>
<td>5.61</td>
<td>10.97</td>
</tr>
<tr>
<td>Small, HISI</td>
<td>84</td>
<td>6.36</td>
<td>11.68</td>
</tr>
<tr>
<td>Large, Pub</td>
<td>115</td>
<td>6.96</td>
<td>12.27</td>
</tr>
<tr>
<td>Large, Private</td>
<td>112</td>
<td>8.08</td>
<td>13.13</td>
</tr>
<tr>
<td>Total</td>
<td>643</td>
<td>6.69</td>
<td>12.09</td>
</tr>
</tbody>
</table>

*MUST and QR scores in alignment.

**Near Most Missed QR with Image**

The attached gauge shows the power output of a small motor up to one-half horsepower (hp). Express the power output shown by the gauge in horsepower (hp), simplifying any fractions. Assume that the sections are evenly spaced.

\[
\begin{align*}
0 \text{ hp} & \quad \% \text{ hp} \\
a: \frac{2}{9} & \quad b: \frac{3}{4} & \quad c: \frac{3}{8} & \quad \frac{3}{16} & \quad e: \frac{4}{3}
\end{align*}
\]

Most Missed QR with Image

13. Choose the answer that best describes a comparison between the number of students from the Midwest and the number of international students.

- The number of students from the Midwest is 2% more than the number of international students.
- Twice as many students come from the Midwest as from international locations.
- There are 2% more students from the Midwest than from international locations.
- The number of international students is 2% more than the number from the Midwest.
- The number of students from the Midwest is 50% more than the number of international students.

MUST vs QR: Gender

<table>
<thead>
<tr>
<th>Gender</th>
<th>n</th>
<th>MUST*</th>
<th>QR*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>308</td>
<td>4.96 (3.79)</td>
<td>10.68 (3.10)</td>
</tr>
<tr>
<td>Male</td>
<td>221</td>
<td>7.56 (4.52)</td>
<td>12.73 (3.46)</td>
</tr>
<tr>
<td>Total</td>
<td>531</td>
<td>6.05</td>
<td>11.54</td>
</tr>
</tbody>
</table>

*MUST and QR scores are in alignment.  
*Males statistically outperformed females on MUST and QR.
## MUST vs QR: Ethnicity

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>MUST*</th>
<th>QR*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-Hispanic</td>
<td>328 (62.4%)</td>
<td>6.81 (4.57)</td>
<td>12.07 (3.40)</td>
</tr>
<tr>
<td>Hispanic</td>
<td>198 (38.6%)</td>
<td>4.67 (3.82)</td>
<td>10.66 (3.12)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>526</strong></td>
<td><strong>6.01</strong></td>
<td><strong>11.54</strong></td>
</tr>
</tbody>
</table>

MUST and QR scores are in alignment. Non-Hispanics statistically outperformed Hispanics on MUST and QR.

## MUST vs QR: Race

<table>
<thead>
<tr>
<th></th>
<th>n (%)</th>
<th>MUST</th>
<th>QR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asian/PI</td>
<td>49 (9.4%)</td>
<td>7.82 (4.75)</td>
<td>12.06 (3.45)</td>
</tr>
<tr>
<td>Mixed</td>
<td>9 (1.7%)</td>
<td>6.33 (4.47)</td>
<td>*11.22 (3.31)</td>
</tr>
<tr>
<td>White</td>
<td>333 (60.3%)</td>
<td>6.05 (4.43)</td>
<td>*11.86 (3.34)</td>
</tr>
<tr>
<td>Black</td>
<td>78 (15.0%)</td>
<td>5.99 (4.28)</td>
<td>11.00 (3.43)</td>
</tr>
<tr>
<td>Native Am/Alaskan</td>
<td>10 (1.9%)</td>
<td>5.70 (4.17)</td>
<td>10.90 (4.41)</td>
</tr>
<tr>
<td>Other</td>
<td>60 (11.6%)</td>
<td>4.58 (3.95)</td>
<td>10.42 (3.40)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>519</strong></td>
<td><strong>6.03</strong></td>
<td><strong>11.55</strong></td>
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*MUST and QR scores are almost in alignment.

## HIGH IMPACT PRACTICES (HIP)

### Your Preference?

- **No Calculator:**
  - “I prefer the chemistry exams *without* a calculator... With a calculator, you could take a long time because you can use the answer and try to work backwards. Without a calculator, you either know it or you don’t.”

- **Calculator:**
  - “I prefer exams with a calculator because I know the process however sometimes I *get nervous* or anxious during exams which hinders my mathematical capabilities and the calculator makes sure that doesn’t get the better of me and that my grade remains intact.”

### Recommend to Future Students?

- **No Calculator:**
  - “Honestly, I think not using a calculator *has better prepared* me for CH302.”

- **Calculator:**
  - “The reason I failed my first two exams in CH301 was because I struggled greatly with *estimating*. I don’t feel like that’s fair because I knew the chemistry and this is a chemistry course.”

### Next Steps

- Determine the degree to which QR skills relate to success in general chemistry
- Implement HIPs
  - Re-awaken numeracy skills
  - Support QR skill development
- Spread the word
  - Numeracy skills are declining in college students
Summary

- Numeracy skills are “low-hanging fruit”
  - MUST identifies at-risk students taking chemistry
  - Number sense is linked to chemistry course success
- Quantitative Reasoning warrants further study
  - Numeracy skills may be limited by reasoning skills
  - Chemistry success may improve as both QR and numeracy skills improve

Acknowledgments

Many thanks to the Networking for Science Advancement (NSA) Team for contributing to this statewide project!

Also, thanks are extended to Eric Gaze for getting the NSA Team started on QL/QR research line and sharing his problems from QLRA with us, and to Peter Brown for allowing us to select problems from his “Number Sense” research collection of problems that can be solved without e-devices!

Questions?

Diagnostic Instruments

- Math-Up Skills Test (MUST): arithmetic skills
  - Authors
    - Hartman (U.S. Naval Academy)
    - Nelson, Chemistry instructor (multi-institutions)
  - Highly reliable (KR-20 = 0.863)
- Diagnostic Algebra Test (DAT)
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Motivation

Expert

Relevance

Competency

Subject Matter
Shared Responsibility

Prior Knowledge

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</tr>
<tr>
<td>Pre-AP</td>
<td>536</td>
<td>79.8 (12.9)</td>
<td>10.4 (4.8)</td>
<td>15.7 (3.4)</td>
<td>357/536 = 66.6%</td>
</tr>
<tr>
<td>Regular</td>
<td>276</td>
<td>76.3 (13.8)</td>
<td>8.9 (4.9)</td>
<td>14.7 (3.6)</td>
<td>138/276 = 50.0%</td>
</tr>
<tr>
<td>None</td>
<td>12</td>
<td>71.2 (13.8)</td>
<td>6.2 (3.5)</td>
<td>13.1 (5.2)</td>
<td>6/12 = 50.0%</td>
</tr>
</tbody>
</table>
# Mathematics

<table>
<thead>
<tr>
<th>Grade</th>
<th>Cal I or II n (avg %)</th>
<th>PreCal n (avg %)</th>
<th>Col Alg n (avg %)</th>
<th>Prob/Stat n (avg %)</th>
<th>None/Dev n (avg %)</th>
<th>No Report n (avg %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>103 (93.5%)</td>
<td>138 (94.1%)</td>
<td>48 (92.5%)</td>
<td>8 (92.7%)</td>
<td>10 (91.9%)</td>
<td>1 (89.3%)</td>
</tr>
<tr>
<td>B</td>
<td>99 (84.6%)</td>
<td>117 (83.7%)</td>
<td>79 (83.5%)</td>
<td>14 (84.6%)</td>
<td>17 (83.7%)</td>
<td>1 (81.6%)</td>
</tr>
<tr>
<td>C</td>
<td>51 (73.9%)</td>
<td>90 (73.7%)</td>
<td>81 (73.2%)</td>
<td>17 (73.7%)</td>
<td>17 (74.5%)</td>
<td>1 (73.6%)</td>
</tr>
<tr>
<td>D</td>
<td>12 (64.5%)</td>
<td>35 (63.3%)</td>
<td>43 (64.3%)</td>
<td>7 (64.3%)</td>
<td>9 (63.3%)</td>
<td>3 (65.7%)</td>
</tr>
<tr>
<td>F</td>
<td>11 (53.5%)</td>
<td>15 (50.5%)</td>
<td>28 (49.9%)</td>
<td>9 (42.0%)</td>
<td>9 (44.1%)</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>276 (83.8%)</td>
<td>395 (82.0%)</td>
<td>279 (75.8%)</td>
<td>55 (72.8%)</td>
<td>62 (73.8%)</td>
<td>6 (65.7%)</td>
</tr>
</tbody>
</table>

Majority of students \((276 + 395/1,073 = 62.5\%)\) currently are enrolled in pre-cal or higher (groups A and B) and have a B average.
Fall 2017 MUST vs. Course Average

\[ y = 1.5036x + 62.198 \]

\[ R^2 = 0.9321 \]
Most-missed Example Problems
(\(< 30\% \text{ correct}\))

- Division with exponential notation:
  \[
  \frac{9.0 \times 10^{-18}}{2.0 \times 10^{-5}} \quad \frac{10^5 \times 10^{23}}{10^{-1} \times 10^{-6}}
  \]

- Logs: Determine the base-10 log of: 1000 = _____ and 0.001 = _____

- Power of 10 square root:  \(\sqrt{64 \times 10^{-12}}\)

- *Division by 0: If A = B, evaluate  \(\frac{A}{A - B}\)

None of 20 questions > 70\% correct!

*New question for fall 2017*
MUST (by institution)
DAT: Algebra Skills

Slope: $m = 1.39$
DAT (by institution)
Letter Grades

Identify the potential D/F students at the beginning of semester (or before) and provide them with the HIPs needed to improve their math-sense!
Prior Knowledge

High School Chemistry Background (Fall 2017)

- Course Avg
- MUST
- DAT
- PreCal +
Correlations & Effect Sizes

Course average \((SD) = 76.75 (15.56)\)

**Correlation \((r)\): MUST:DAT = 0.700**

<table>
<thead>
<tr>
<th></th>
<th>(n = 3.266)</th>
<th>Max = 20 points</th>
<th>Correlation to Avg</th>
<th>(R^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MUST</td>
<td>7.75 = 38.75%</td>
<td>0.398</td>
<td>0.158</td>
<td></td>
</tr>
<tr>
<td>DAT</td>
<td>14.71 = 73.55%</td>
<td>0.324</td>
<td>0.105</td>
<td></td>
</tr>
</tbody>
</table>

**Effect Size DAT : Course Avg = .206 [small]**
indicating 50% chance of predicting average from DAT (algebra skills)

**Effect Size MUST : Course Avg = 2.22 [huge]**
indicating that there is a 80% chance (or greater) of predicting course average from MUST (arithmetic skills)
### Predictability of MUST Ranges (Fall 2017)

<table>
<thead>
<tr>
<th>MUST Range</th>
<th>$n$</th>
<th>Average ($SD$) ($SE$)</th>
<th>$n$ with Average &lt; 69.5% (% in MUST range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Above average (&gt; 12)</td>
<td>392</td>
<td>87.05 (8.85) (0.45)</td>
<td>12 (3.06%)</td>
</tr>
<tr>
<td>Average (8-12)</td>
<td>347</td>
<td>80.42 (10.90) (0.59)</td>
<td>45 (12.97%)</td>
</tr>
<tr>
<td>Below average (&lt; 8)</td>
<td>334</td>
<td>70.85 (13.71) (0.75)</td>
<td>123 (36.82%)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1073</strong></td>
<td><strong>79.86 (13.02) (0.40)</strong></td>
<td><strong>180 (16.78%)</strong></td>
</tr>
</tbody>
</table>
**Average Student Profile**

**Preparation**
- Graduated from TX High School
- Took Pre-AP Chemistry
- First-time in course (Avg = 76%)
- STEM major
- Co-enrolled in Pre-Calc or higher
- Plans to take Chem II

**College**

**Nonacademic**
- Parents and grandparents have some college
- Does not work

**Graduated from TX High School**
- Took Pre-AP Chemistry
AY 3: QR Introduction
Quantitative Reasoning (Fall 2018)

\[ N = 643; \text{correlation between MUST and QR} = 0.658 \text{ (a little lower than with the DAT, } r = 0.700); \text{mean on MUST} = 6.69; \text{mean on QR} = 12.09 \]
Most Missed QR Arithmetic

0.8% means:

a. 8 out of 100  b. 0.8  c. 8.0  d. 0.08  e. \(\frac{0.8}{100}\)
Most Missed QR Word Problems

Let $U_A = \frac{r}{1-U_B}$. Solve this equation for $U_B$ in terms of $U_A$ and $r$.

- a. $\frac{r-U_A}{r}$
- b. $\frac{r-U_A}{U_A}$
- c. $\frac{1-r}{U_A}$
- d. $\frac{U_A-r}{r}$
- e. $\frac{U_A-r}{U_A}$

In a certain company there are 3 times as many men working as women. What is the fraction of employees that are female?

- a. $\frac{1}{3}$
- b. $\frac{3}{10}$
- c. $\frac{2}{3}$
- d. $\frac{3}{4}$
- e. $\frac{1}{4}$
The attached gauge shows the power output of a small motor up to one-half horsepower (hp). Express the power output shown by the gauge in horsepower (hp), simplifying any fractions. Assume that the sections are evenly spaced.

a. 2/9  b. 3/4  c. 3/8  d. 3/16  e. 4/3
19. Choose the answer that best describes a comparison between the number of students from the Midwest and the number of International students.

**Home Region Entering Class 2010**

- New England: 43%
- Mid Atlantic: 26%
- Midwest: 6%
- South: 5%
- West: 13%
- International: 4%
- Southwest: 3%

**Possible Answers:**

a. The number of students from the Midwest is 2% more than the number of International students.
b. Twice as many students came from the Midwest as from International locations.
c. There are 25 more students from the Midwest than from International locations.
d. The number of International students is 25% more than the number from the Midwest.
e. The number of students from the Midwest is 50% more than the number of International students.
# MUST vs QR: Institution

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>MUST</th>
<th>QR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small, HSI</td>
<td>71</td>
<td>2.23</td>
<td>9.75</td>
</tr>
<tr>
<td>Middle, Pub</td>
<td>76</td>
<td>5.26</td>
<td>10.20</td>
</tr>
<tr>
<td>Large, HSI</td>
<td>79</td>
<td>5.61</td>
<td>10.97</td>
</tr>
<tr>
<td>Small, HSI</td>
<td>84</td>
<td>6.36</td>
<td>11.68</td>
</tr>
<tr>
<td>Large, Pub</td>
<td>115</td>
<td>6.96</td>
<td>12.27</td>
</tr>
<tr>
<td>Large, Pub</td>
<td>112</td>
<td>8.08</td>
<td>13.13</td>
</tr>
<tr>
<td>Small, Private</td>
<td>106</td>
<td>10.00</td>
<td>14.87</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>643</td>
<td>6.69</td>
<td>12.09</td>
</tr>
</tbody>
</table>

*MUST and QR scores are in alignment.*
### MUST vs QR: Gender

<table>
<thead>
<tr>
<th></th>
<th>$n$</th>
<th>MUST*</th>
<th>QR*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>308</td>
<td>4.96 (3.78)</td>
<td>10.68 (3.10)</td>
</tr>
<tr>
<td>Male</td>
<td>221</td>
<td>7.56 (4.92)</td>
<td>12.73 (3.40)</td>
</tr>
<tr>
<td>Total</td>
<td>531</td>
<td>6.05</td>
<td>11.54</td>
</tr>
</tbody>
</table>

MUST and QR scores are in alignment.

*Males statistically outperformed females on MUST and QR.
MUST vs QR: Ethnicity

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>MUST*</th>
<th>QR*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-Hispanic</td>
<td>328 (62.4%)</td>
<td>6.81 (4.57)</td>
<td>12.07 (3.40)</td>
</tr>
<tr>
<td>Hispanic</td>
<td>198 (38.6%)</td>
<td>4.67 (3.82)</td>
<td>10.66 (3.12)</td>
</tr>
<tr>
<td>Total</td>
<td>526</td>
<td>6.01</td>
<td>11.54</td>
</tr>
</tbody>
</table>

MUST and QR scores are in alignment. Non-Hispanics statistically outperformed Hispanics on MUST and QR.
## MUST vs QR: Race

<table>
<thead>
<tr>
<th></th>
<th>n (%)</th>
<th>MUST</th>
<th>QR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asian/PI</td>
<td>49 (9.4%)</td>
<td>7.82 (4.75)</td>
<td>12.06 (3.45)</td>
</tr>
<tr>
<td>Mixed</td>
<td>9 (1.7%)</td>
<td>6.33 (4.47)</td>
<td>*11.22 (3.31)</td>
</tr>
<tr>
<td>White</td>
<td>313 (60.3%)</td>
<td>6.05 (4.41)</td>
<td>*11.86 (3.24)</td>
</tr>
<tr>
<td>Black</td>
<td>78 (15.0%)</td>
<td>5.99 (4.28)</td>
<td>11.00 (3.43)</td>
</tr>
<tr>
<td>Native Am/Alaskan</td>
<td>10 (1.9%)</td>
<td>5.70 (4.17)</td>
<td>10.90 (4.41)</td>
</tr>
<tr>
<td>Other</td>
<td>60 (11.6%)</td>
<td>4.58 (3.95)</td>
<td>10.42 (3.40)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>519</strong></td>
<td><strong>6.03</strong></td>
<td><strong>11.55</strong></td>
</tr>
</tbody>
</table>

*MUST and QR scores are almost in alignment.*
HIGH IMPACT PRACTICES (HIP)
Your Preference?

- No Calculator:
  - “I prefer the chemistry exams *without* a calculator... With a calculator, you could take a *long time* because you can use the answer and try *to work backwards*. Without a calculator, you either know it or you don’t.

- Calculator:
  - “I prefer exams with a calculator because I know the process however sometimes *I get nervous* or anxious during exams which hinders my mathematical capabilities and *the calculator makes sure* that doesn’t get the better of me and that *my grade remains intact*.”

**PREFERENCE FOR CHEMISTRY EXAMS?**

- Calculator: 10%
- No Calculator: 11%
- Both/Either: 79%

*n=70*
Recommend to Future Students?

- **No Calculator:**
  - “Honestly, I think not using a calculator has *better prepared* me for CH302.”

- **Calculator:**
  - “The *reason I failed* my first two exams in CH301 was because I struggled greatly with *estimating*. I don’t feel like that’s fair because I knew the chemistry and this is a chemistry course.”

**FUTURE CH301 CLASSES?**

- No-Calculator Exams: 96%
- Calculator Exams: 4%

n=69
Next Steps

• Determine the degree to which QR skills relate to success in general chemistry

• Implement HIPs
  – Re-awaken numeracy skills
  – Support QR skill development

• Spread the word
  – Numeracy skills are declining in college students
Summary

• Numeracy skills are “low-hanging fruit”
  – MUST identifies at-risk students taking chemistry
  – Number sense is linked to chemistry course success

• Quantitative Reasoning warrants further study
  – Numeracy skills may be limited by reasoning skills
  – Chemistry success may improve as both QR and numeracy skills improve
Acknowledgments

Many thanks to the Networking for Science Advancement (NSA) Team for contributing to this statewide project!

Also, thanks are extended to Eric Gaze for getting the NSA Team started on QL/QR research line and sharing his problems from QLRA with us, and to Peter Brown for allowing us to select problems from his “Number Sense” research collection of problems that can be solved without e-devices!
Questions?

MAYBE THIS IS A QUESTION THAT SHOULD BE LEFT TO THE PHILOSOPHERS.
Diagnostic Instruments

• Math-Up Skills Test (MUST): arithmetic skills
    • Quiz: http://bit.ly/1HyamPc *(Named: MUST)*
  – Authors
    • Hartman (U.S. Naval Academy)
    • Nelson, Chemistry instructor (multi-institutions)
  – Highly reliable \((KR-20 = 0.863)\)

• Diagnostic Algebra Test (DAT)