Multidimensional Measurement in Education

Laura Tucker, Mazur Group
Harvard Physics Postdoc Retreat, 10/18/2013
Ultrafast laser physics
Ultrafast laser physics
Why multidimensional measurement?
Why multidimensional measurement?

Learning
Why multidimensional measurement?

Learning:
- Standardized tests
- Force concepts (FCI)
- Mechanics concepts and problem-solving (MBT)

Hestenes, et. al. 1992; Hestenes & Wells. 1992
Why multidimensional measurement?
Why multidimensional measurement?

Metacognition: “thinking about, and planning control of, one’s own thinking”

Girash, J. (2013)
Why multidimensional measurement?

Metacognition: “thinking about, and planning control of, one’s own thinking”
related to transfer of learning to new situations

The National Research Council (2000)
Why multidimensional measurement?

Learning

Metacognition

Interaction
Why multidimensional measurement?

“new perspective, corrective feedback, ... line of reasoning to pursue”

Interaction:

Chi (2009)
Why multidimensional measurement?

Interaction:

“new perspective, corrective feedback, ... line of reasoning to pursue”

“create a shared mental model... neither...may have been able to come up with the shared understanding on her own”

Chi (2009)
Why multidimensional measurement?

- Learning
- Metacognition
- Interaction
- Self-efficacy
Why multidimensional measurement?

“a person’s situation-specific belief that he or she can succeed in a given domain”

Self-efficacy:

Fencl & Scheel (2005)
Why multidimensional measurement?

Self-efficacy: “a person’s situation-specific belief that he or she can succeed in a given domain”

Fencl & Scheel (2005)
Why multidimensional measurement?

- Learning
- Metacognition
- Interaction
- Self-efficacy
Why multidimensional measurement?

- Learning
- Metacognition
- Interaction
- Self-efficacy
Lens to Learning

Measurement

Interaction
Measurement

Interaction
Group exams
Check self/peer assessment

**Title**

Peer Evaluate 'Fauzy Wan'

**Participation**

- Never
- Rarely
- Sometimes
- About half the time
- Most of the time
- All the time
- Participates fully in team activities.

**Well-prepared**

- Never
- Rarely
- Sometimes
- About half the time
- Most of the time
<table>
<thead>
<tr>
<th>Team</th>
<th>Teammate Name</th>
<th>Relative Contribution</th>
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<tbody>
<tr>
<td>Team 19</td>
<td>Jerry</td>
<td>-3 -2 -1 0 1 2 3</td>
</tr>
<tr>
<td>Team 19</td>
<td>Duo</td>
<td>-3 -2 -1 0 1 2 3</td>
</tr>
<tr>
<td>Team 19</td>
<td>Helan</td>
<td>-3 -2 -1 0 1 2 3</td>
</tr>
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</table>
Positive dynamics:

Partnering. Good at motivating others to work long hours to meet a deadline

Empathizing. Takes time to understand perspectives when differences of opinion occur

Negative dynamics:

Dismissive. Makes an effort to listen to team members’ ideas (not dismissive)
5.3.2 Atomic sizes and substance densities

Hydrogen has a diameter of 1 Å. A useful consequence is the rule of thumb that a typical interatomic spacing is 3 Å. This approximation gives a reasonable approximation for the densities of substances, as this section explains.

Let \( A \) be the atomic mass of the atom; it is (roughly) the number of protons and neutrons in the nucleus. Although \( A \) is called a mass, it is dimensionless. Each atom occupies a cube of side length \( a \approx 3 \, \text{Å} \), and has mass \( \frac{A m_{\text{proton}}}{(3 \, \text{Å})^3} \).

The density of the substance is

\[
\rho = \frac{\text{mass}}{\text{volume}} = \frac{A m_{\text{proton}}}{(3 \, \text{Å})^3}.
\]

You do not need to remember or look up \( m_{\text{proton}} \) if you multiply this fraction by unity in the form of \( \frac{N_A}{N_A} \), where \( N_A \) is Avogadro’s number:

\[
\rho = \frac{A m_{\text{proton}} N_A}{(3 \, \text{Å})^3 N_A}.
\]

The numerator is \( A \, \text{g} \), because that is how \( N_A \) is defined. The denominator is

\[
3 \times 10^{-23} \, \text{cm}^3 \times 6 \times 10^{23} = 18.
\]

So instead of remembering \( m_{\text{proton}} \), you need to remember \( N_A \). However, \( N_A \) is more familiar than \( m_{\text{proton}} \) because \( N_A \) arises in chemistry and physics. Using \( N_A \) also emphasizes the connection between microscopic and macroscopic values. Carrying out the calculations:

\[
\rho = \frac{A}{18} \, \text{g cm}^{-3}.
\]
5.3.2 Atomic sizes and substance densities

Hydrogen has a diameter of 1 Å. A useful consequence is the rule of thumb that a typical interatomic spacing is 3 Å. This approximation gives a reasonable approximation for the densities of substances, as this section explains.

Let $A$ be the atomic mass of the atom; it is (roughly) the number of protons and neutrons in the nucleus. Although $A$ is called a mass, it is dimensionless. Each atom occupies a cube of side length $\alpha \sim 3 \, \text{Å}$, and has mass $A m_{\text{proton}}$.

The density of the substance is

$$\rho = \frac{\text{mass}}{\text{volume}} = \frac{A m_{\text{proton}}}{(3 \, \text{Å})^3}.$$

You do not need to remember or look up $m_{\text{proton}}$ if you multiply this fraction by unity in the form of $N_A/N_A$, where $N_A$ is Avogadro's number:

$$\rho = \frac{A m_{\text{proton}} N_A}{(3 \, \text{Å})^3 N_A}.$$

The numerator is $A$ g, because that is how $N_A$ is defined. The denominator is

$$3 \times 10^{-23} \, \text{cm}^2 \times 6 \times 10^{-23} = 18.$$

So instead of remembering $m_{\text{proton}}$, you need to remember $N_A$. However, $N_A$ is more familiar than $m_{\text{proton}}$ because $N_A$ arises in chemistry and physics. Using $N_A$ also emphasizes the connection between microscopic and macroscopic values. Carrying out the calculations:

$$\rho \approx \frac{A}{18} \, \text{g cm}^{-3}.$$

Zyto et. al.
The NB system: text annotation
The NB system: text annotation

<table>
<thead>
<tr>
<th>Score</th>
<th>Description &amp; Criteria</th>
</tr>
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<tbody>
<tr>
<td>2</td>
<td>Demonstrates thorough and thoughtful reading AND insightful interpretation of the text.</td>
</tr>
<tr>
<td>1</td>
<td>Demonstrates reading, but no (or only superficial) interpretation of the text.</td>
</tr>
<tr>
<td>0</td>
<td>Does not demonstrate any thoughtful reading of the text.</td>
</tr>
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Learning
Metacognition
Interaction
Self-efficacy
Learning NB annotations

Interaction Lens to Learning videos

Measurement Group exams

Interaction Social networks

Learning Peer assessments


Sue Borchardt, 2011

http://www.youtube.com/watch?v=Wzs2zXI_aZc&noredirect=1

Helan Wu and Eric Mazur, 2013
