

# **The Role of Representations in Research-Based Instructional Practice in Physics**

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# Why are Multiple Representations Useful in Learning Science?

- Can increase working memory by utilizing parallel processing systems (e.g., Paivio, “Dual-Coding Theory,” 1971: verbal and imagery)
- Can help to link and organize separate ideas, making them easier to remember
- May be required for full understanding of particular concepts (McDermott, 1990; Hestenes, 1997)

# Are “Spatial Abilities” Correlated with Learning Science?

- Researchers in chemical education probed relation between students’ “spatial visualization” abilities and their performance on ***non-spatial*** chemistry problems
- Some evidence of positive correlation (Bodner and McMillen, 1986), ***but:***
  - ***Training or practice can improve achievement on spatial chemistry problems (e.g., Small and Morton, 1983)***
  - ***Content knowledge or general academic ability may be confounding variables (Baker and Talley, 1972)***

# Are There Subject-Specific Learning Difficulties with Representations?

- Much evidence says **yes**: Meltzer (2005) and many references cited therein; Kohl and Finkelstein (2005); Torigoe and Gladding (2007)
- Detecting presence of such difficulties is much easier than uncovering their *causes* (*i.e.*, the specific student reasoning difficulties and behaviors)
- Information about causes is *required* in order to address the problems effectively.

# Certain Representations May Facilitate Learning in Specific Contexts

Representations can be developed to address specific learning difficulties identified in research:

- Example: “double-headed force arrow” or “interaction diagrams” to address difficulties with Newton’s third law (Jimenez and Perales, 2001; Savinainen, Scott, and Viiri, 2005; Hinrichs, 2005; Savinainen, Nieminen, Mäkynen and Viiri, 2013)
- Example: Use of specific step-by-step problem-solving strategy for use of free-body diagrams (Rosengrant, Van Heuvelen, and Etkina, 2005)
- Example: PV diagrams in thermodynamics (Meltzer, 2004)

# Is Animation an Effective Learning and Diagnostic Tool?

- Animated versions of *some* FCI questions may be *more valid* diagnostics of student thinking than the static versions (Dancy and Beichner, 2006)
- ***But:*** Many animations contain additional information relative to static versions, so may not be fully equivalent tests (Tversky, Morrison, and Betrancout, 2002)

## Do Students Who Use Multiple Representations Have Better Problem Solving Performance?

- Some evidence says use and performance may sometimes be *correlated* (Rosengrant, Van Heuvelen, and Etkina, 2005, 2006; De Leone and Gire, 2006; )
  - However: causality *was not demonstrated!*
- Other evidence shows that students who spontaneously use multiple representations may *not* be more successful than those who do not (Kohl and Finkelstein, 2005)

*Conclusion: Depends on context; can not generalize.*

# Are There Consistent Patterns of Difficulties?

- 1) Are students consistent in which representations cause *them* difficulties?
- 2) Are certain forms of representation of a particular topic consistently difficult for all students?
- 3) Can students choose which representation works best for them?
- 4) Does increased instructional emphasis on multiple representations decrease discrepancies in students' inter-representational performances?



(1) Are particular students consistent in which representations cause *them* difficulties?

- Evidence so far does *not* support this hypothesis. (Meltzer, 2005; Kohl and Finkelstein, 2005).

(2) Are certain forms of representation of a particular topic consistently difficult for most students?

- Evidence (previously cited; also Nieminen, Savinainen, and Viiri, 2010) suggests that *certain specific representations* may be difficult for most students, but no evidence exists that all representations of a particular type (e.g., graphical) are difficult for most students. (However, gender differences may exist.)

### (3) Can Students Choose Which Representation Works Best For Them?

- Students often describe themselves as “visual” or “mathematical” learners (e.g., Kohl and Finkelstein, 2005)
- Kohl and Finkelstein (2005) found that students given a choice of problem format (verbal, graphical, pictorial, mathematical) *sometimes* do better, and *sometimes* do worse than students randomly assigned a format. (*Note: students did not see problems before making choice*)

(4) Does increased instructional emphasis on multiple representations decrease discrepancies in students' inter-representational performances?

- Kohl and Finkelstein (2005) claim that discrepancies between performance on random-assignment and student-chosen assignment on multiple-representation problems is *lower* for classes in which there was much more extensive use of multiple representations in lectures, exams, etc.

# Gender Related Issues

- Important to explore possible differences in male/female responses to various representations; relatively little data so far;
- Meltzer (2005) found evidence that females *may* have particular difficulties with certain formats in specific contexts (e.g., circuit diagrams)
  - Reason for this is not clear: could it be different preparation and/or background?
  - Marshall (unpublished, 2006) found evidence that females may not be as familiar with certain circuit-diagram conventions (e.g., use of geometric shapes/straight lines, etc.)

# Methodological Difficulties: Threats to Validity

- Problems posed with different representations may not be truly equivalent to each other.
- Inconsistencies in student responses create large data fluctuations: *replication is important!*
- Variations in student background and preparation can generate large discrepancies in their responses: *non-random assignment of test subjects is particularly risky!*

# Non-Equivalence of Problems

*It is extremely difficult to create truly **equivalent** multi-representational versions of the same problem*

- diagrams, pictures, etc. may contain additional information not present in other versions;
- slight differences in format may cue students strongly to use different solution methods (e.g., energy conservation vs. kinematics in a mechanics problems);
- requirement for mathematical calculations in only some versions may introduce extraneous factor (unrelated to representation format itself);

# Summary

- Multiple representations can be an effective aid to student learning of physics concepts
- Learning difficulties and learning enhancements with specific representations are highly topic- and context-dependent, requiring focused research to optimize effective pedagogical use of multiple representations