Multiple Representations in Physics Education: Recent Developments and Questions for Future Work

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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” to address difficulties with Newton’s third law (Jimenez and Perales, 2001; Savinainen, Scott, and Viiri, 2005; Hinrichs, 2005)
- Example: Use of specific step-by-step problem-solving strategy for use of free-body diagrams (Rosengrant, Van Heuvelen, and Etkina, 2005)

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 recent 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) 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 (preprint 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);