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A Reply: Media and Methods

□ Robert B. Kozma

Media and methods together influence learning. This article illustrates an approach to research that allows us to look at the cognitive mechanisms by which learners interact with instructional designs and use media and methods to construct understanding. It critiques Clark's (1994) replaceability challenge.

□ No particular medium is necessary for learning, nor is a particular method. However, both media and methods influence learning and they frequently do it by influencing each other. In a good design, media and methods are inexorably confounded. Media constrain and enable methods, or as Reiser (1994) puts it, ". . . certain media attributes make certain methods possible" (p. 45). Conversely, methods take advantage of a medium's capabilities in well-designed instruction. While learning, students interact with both media and methods and, as Jonassen, Campbell, and Davidson (1994) point out, it is difficult, if not impossible, to isolate the effects of media and methods. One cannot simply replace one medium with another in a design and hold everything else constant, as Clark (1994) suggests.

Rather than trying to pull them apart in our research designs, we should examine the cognitive and social mechanisms by which students interact with media and methods as they learn. In this brief reply, I would like to describe a study that we have done which illustrates what I consider to be a more productive approach to research, one that can inform both theory and practice. And one that addresses some of the points made by Reiser (1994) and Jonassen et al. (1994).

Looking at mechanisms. In our study, reported in more detail elsewhere (Kozma, Russell, Jones, Marx, and Davis, in press), we used a multimedia software package that we have designed for chemistry. Our software, entitled *MultiMedia and Mental Models in Chemistry* or *4M:Chem*, is a computer-based chemistry environment in which students can conduct experiments to understand equilibrium systems and how they change. To describe the system in brief: Students select a chemical system and operate on

it in some way (e.g., increase temperature, reduce pressure, etc.). They then see the effect of their actions in simultaneously displayed multiple, dynamic representations including video segments of the reaction, dynamic graphs of concentrations, and molecular-level animations of the reaction.

So, for example, students could select a gaseous system of two species at equilibrium and increase its temperature. The Video Window shows the system, as it appears on the laboratory bench, being heated and changing color as the equilibrium shifts. In synchrony with the video and in a window next to it, a dynamic graph shows an increase in partial pressure that plateaus as the system reaches a new equilibrium. The Animation Window shows two types of molecules (one colored, one colorless) moving, colliding, and reacting. As the system is heated, the molecules speed up and reactions result in more colored molecules, at the same time that the color of the system changes in the Video Window. At the new equilibrium point, students can make the observation that while the color remains constant in the Video Window and the partial pressures plateau in the Graph Window, the molecules are still moving and reacting in the Animation Window. This is the mental model that experts have of a system at equilibrium.

We asked two professors to use *4M:Chem* as an aid to their lectures over the two-session period that addresses equilibrium. A total of 295 students attended both lectures and responded to both pretests and posttests given during the sessions. There were no control or comparison groups in this study. The mean score on the brief pretest score was 3.18 ($sd=1.75$); the mean posttest score was significantly greater at 5.50 ($sd=2.49$, $t=15.61$, $p<.0001$). Of particular importance was the decrease in student misconceptions. There are five misconceptions that students frequently have related to equilibrium (Kozma, Russell, Johnston, & Dershimer, 1990). For example, students frequently assert that at equilibrium, concentrations of products and reactants are equal or that at equilibrium the reaction comes to a stop. On the pretest, students mentioned a mean of .50 ($sd=.60$) misconceptions; on the posttest, the mean was only .20 ($sd=.43$), a

reduction of over 50% ($t=-7.58$, $p<.0001$).

Clearly, students used this system to learn some important things about equilibrium. However the question remained, how did this learning take place? What influenced it? Was it the lecturer, the content, the method, the medium, the students themselves? Quite likely each of these played a role. But what role? These questions are not answered with control groups and pretest to posttest differences. To answer these questions we must look at learning as it happens and collect data on the ways students interact with the system as they learn.

To answer some of these questions, we went into the experimental laboratory.¹ Five students participated in this second phase of the study; they were from the same chemistry course as students in the study above but from a lecture section that did not use the software. Each student used the software individually along with a laboratory manual to conduct experiments of the sort used in the lecture study. The students were instructed to "think out loud" as they used the manual and the software.

The results on pretests and posttests paralleled those in the lecture study. To examine how the learning occurred, we identified the specific items that each student got right on the posttest that he or she had answered incorrectly on the pretest. We then looked through the protocols to identify the specific points at which learning seemed to occur and examined the interactions between the students and the software to see if we could determine causal mechanisms.

The data suggest that students learned by integrating information across representations—information that is specific to each representation—in order to make a series of inferences that together constitute an understanding of the effect of temperature on equilibrium. The protocol from one student illustrates this nicely. Here the student watches the video and notes:

¹ In an extension of this research we are also looking at the learning process in more natural social settings, students listening to lectures and working in diads in the chemistry computer laboratory.

... (mumble) mixture is getting darker, reddish um ... mixture is heated

She then connects in the video with the shift in the number of molecules:

... mixture into the hot um, the molecules are moving the NO_2 is becoming a (mumble) the um ... N_2O_4 um ...

And finally, she connects the video with the shift in equilibrium, as expressed

Heated ... the concentration of the N_2O_4 decreases. because it's at equilibrium else.

While using *4M:Chem* to make a series of observations that as you heat increase their speed, result in the colored equilibrium the concentration (sure) becomes constant continue to occur in learned. These data was influenced by the methods we used in our

Challenging the representation (1994) suggests the "criteria" for judging whether ever we find a study to foster learning with other medium that gains. According to replaced with similar some method shared the medium.

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... (mumble) mixture into hot water. The mixture is getting darker, reddish brown, so um . . . as the . . . um . . . mixture is heated, it becomes darker.

She then connects heating and color change in the video with the increased motion and shift in the number of molecules in the animation:

... mixture into the hot water and as he does so, he um, the molecules are moving a lot more rapidly and the NO₂ is becoming a lot more dominant . . . um, (mumble) the um . . . N₂O₄ doesn't exist as much as um . . .

And finally, she also connects heating in the video with the constant concentration at equilibrium, as expressed by the graph:

Heated . . . the concentration of NO₂ increases while the N₂O₄ decreases. Then it becomes constant because it's at equilibrium and it can't do anything else.

While using *4M:Chem*, the student was able to make a series of inferences to understand that as you heat this system, molecules increase their speed, their collisions more often result in the colored species, and at the new equilibrium the concentration (or partial pressure) becomes constant, although reactions continue to occur in both directions; that is, she learned. These data suggest that this learning was influenced by the medium and the methods we used in our design.

Challenging the replaceability challenge. Clark (1994) suggests the following "armchair criteria" for judging our research designs: whenever we find a study where a medium appears to foster learning we must see if there is some other medium that would yield similar learning gains. According to Clark, if a medium can be replaced with similar results, the "cause" is some method shared by both treatments, not the medium.

It is difficult for me to apply the replaceability challenge to the above study. It is hard for me to imagine some other medium that would allow us to "deliver" the same "underlying method." When we designed this system, the methods that we used were built around the

capabilities of this new medium. Frankly, we could not have created this design without multimedia computing. If we change the medium, we would have to completely redesign our methods, a point made by Morrison (1994).

The replaceability challenge does not advance our thinking about media, methods, or what causes learning. Indeed, the replaceability challenge says nothing at all about causes, and that is its principal failing. If two treatments yield a similar outcome it does not mean that they resulted from the same cause. And even if they happen to have a shared cause, a "replacement study" certainly does not identify what that cause is. It seems to me that if you want to know what causes learning, you have to look at it as it occurs. And if you do, I suspect you will find that learning is influenced by media and methods together, as they did in the study above.

CONCLUSION

I agree with Shrock (1994) that the discussion of the role of media in learning is an important one for the field of instructional technology. This discussion can ". . . clarify who we are, what we are trying to do, what we know, and how we might best invest the limited resources devoted to future research" (p. 49). It is time to shift the focus of our research from media as conveyors of methods to media and methods as facilitators of knowledge-construction and meaning-making on the part of learners (Jonassen et al., 1994; Kozma, 1991; Salomon, Perkins, & Globerson, 1991). □

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