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Exploring Faculty Decision-Making Processes for Using Instructional Technology in the Classroom

Implications for Policy and Practice

By Matthew Tadashi Hora and Jeremiah Isaac Holden

Key Points

1. The adoption, adaptation, or rejection of technology-based teaching innovations is influenced by alignment among (a) pre-existing faculty beliefs and goals, (b) perceived affordances of particular tools, and (c) cultural conventions in the disciplines.
2. Some faculty experiment with teaching tools that conform with disciplinary conventions but also take advantage of digital technologies.
3. Policymakers and campus leaders should consider how well proposed teaching innovations align with existing local practices and disciplinary conventions before trying to implement them.

About the Authors

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Introduction

Instructional technology is an increasingly common feature of the university classroom and a key element in many pedagogical reform initiatives. For example, the America Competes Act of 2007 directs the Office of Science and Technology Policy and the National Science Foundation to identify promising practices in science, technology, engineering, and mathematics (STEM) classrooms.

Many of these practices focus on expanding faculty[1] teaching beyond traditional lecturing to include techniques like *problem-based learning* and *Peer Instruction*, which actively engage students with the material and each other. And many of these new approaches utilize instructional technology, such as *classroom-response systems* (clickers) or web-based simulations, as a way to facilitate these interactions.[2 3] For example, the University of Colorado-Boulder (CU-Boulder) has equipped most of its classrooms with clickers and provides many professional development opportunities for faculty and graduate students to learn how to use them effectively.

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Given the primacy of instructional technology in today's college classroom, it is important to understand the dynamics surrounding faculty use of these tools, especially how specific tools are adapted to meet the unique needs of particular faculty or instructional situations. While some adaptations maintain the original pedagogical intent of the designers, others are "lethal mutations" that subvert these intentions and result in ineffective classroom uses.[4] For example, investment in classroom clickers at CU-Boulder has not automatically translated into more effective pedagogy: research indicates that some faculty use clickers to facilitate student learning while others use them for low-level tasks (e.g., taking attendance) or in pedagogically ineffective ways (e.g., giving students insufficient time to answer questions).[5] In other cases, technological innovations may simply be rejected out of hand.[6]

But blame for a lack of diffusion of pedagogical innovations cannot be laid solely at the feet of instructors; instructional designers and policymakers face the challenge of introducing innovations into established patterns of tool use and educational practice.[7] It is well known that teachers will appraise the utility and desirability of innovations in light of their existing beliefs, workplace constraints, and classroom practices.[8] For example, an initiative to reform introductory engineering courses by streamlining course administration through new software systems faltered because it demanded onerous time commitments, a considerable barrier for research-oriented faculty.[9]

As a result, when interventions are designed and implemented without a working understanding of existing practices and workplace conditions, incompatibilities between the demands of the innovation and the constraints of the local setting may result.[10] For these reasons, researchers argue that "resistance" should be understood not solely as a knee-jerk reaction against an innovation but also as a principled and defensible response to a poorly designed intervention.[11] Thus, instructional designers need robust accounts of local practice, which can ground the design of new initiatives and provide insights into why initiatives are encountering resistance or undesirable adaptations.

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Systems-of-Practice: Towards Comprehensive Accounts of Faculty Teaching

It is not uncommon for teaching to be conceptualized solely as the overt pedagogical techniques used in the classroom, such as lecturing, the use of clickers, or small-group work. But describing faculty teaching in this way obscures two critical aspects of instruction: 1) the importance of course planning and the influence of organizational contexts and individual characteristics on this process,[12] and 2) the multi-dimensional nature of classroom instruction (i.e., it includes features—beyond pedagogical techniques—that interact throughout a class period). Research on K-12 teaching and school leadership is increasingly moving away from a view of practitioners as "lone heroes" who make decisions and act in isolation with little input or influence from other people or organizational constraints and characteristics.[13] Instead, teaching is best viewed as a *system-of-practice*, which is comprised of the "dynamic interplay of artifacts and tasks that inform, constrain, and constitute local practice."[14]

In regard to course planning, this view suggests that faculty will "read" their environments and determine how local policies, procedures, and resources will constrain or afford their decisions about teaching. For example, when planning for class, faculty will draw upon the technology-related resources that they know their departments provide. Thus, it is important to account for the technology that faculty recognize as being available and salient to their work.

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The selection of pedagogical techniques and instructional technologies also is influenced by teachers' pre-existing *schemata* (i.e., mental structures or representations), which are activated in particular situations to guide their planning and classroom teaching.[15] These schemata include

- beliefs about course content, students, and learning;
- personal experiences;
- instructional goals;
- *perceived affordances*, or perceptions of possible actions in a given situation or context;[16] and
- *lesson scripts*, or routinized actions, such as regularly showing PowerPoint slides.

Each of these schemata is shaped within specific academic communities and, over time, can become *cultural conventions* that guide individuals' behavior.

Finally, teaching practice is a complex and multi-dimensional phenomenon that includes

- the variety of teaching methods used (e.g., lecturing, posing questions, small-group work, etc.),
- the types of *cognitive engagement* involved (i.e., the type of student thinking elicited in the classroom), and
- the types of instructional technology used.

Capturing how technology is used in conjunction with other teaching methods or cognitive engagement would shed important light on how tools are used and in what combinations. To better capture the complexity of classroom instruction, we developed the Teaching Dimensions Observation Protocol (TDOP),[17] which is designed to collect data on these three dimensions of teaching every five minutes as they are used throughout a class.

This brief presents findings from an empirical analysis of course planning and classroom teaching related to instructional technology with the specific aim of providing actionable evidence for policymakers and practitioners. In particular, this analysis focuses on describing the types of instructional technologies faculty consider as part of their local resource base, the specific decision-making "pathways" related to the incorporation of technology into lesson plans, and how faculty actually use technology in the classroom.

Methods

Funded by the National Science Foundation, the Culture, Cognition, and Evaluation of STEM Higher Education Reform (CCHER) project is a mixed-methods study that examines the cognitive, cultural, and structural aspects informing STEM faculty teaching practices at the undergraduate level.[18] In the spring of 2010, researchers interviewed and observed 40 instructors in three disciplines (mathematics, biology, physics) at three research universities, including the University of Wisconsin–Madison. Each instructor was interviewed once to identify specific features of their course-planning behaviors and observed twice.

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Interviews were transcribed and analyzed using 1) thematic analysis to identify the local resource base for instructional technology and 2) causal network analysis to identify the specific decisions that lead to the inclusion or exclusion of technology being included in a lesson. Classroom observations were conducted using TDOP. The observation data were analyzed for groups of faculty within each discipline who exhibited similar technology-related decision-making pathways. These data are reported descriptively as percentages of total intervals in which particular codes were observed and through *social network analysis*, which depicts how often pairs of codes were observed together. Given the primacy of the discipline in forming both administrative and cultural units, all data are analyzed separately for each disciplinary group.

Which tools comprise the local resource base for instructional technology?

The answer to this question is important because it represents the technological resources that faculty are aware of in their workplace and, thus, which are likely to be drawn upon for use in the classroom. Interview data were closely analyzed for references to tools that were either actively used by or referenced as being available to faculty. Each disciplinary group reported nearly the same number of tools, with the most prevalent tools reported in common being chalkboards, clickers, and course websites (see Table 1).

Unsurprisingly, all faculty reported the chalkboard as a ubiquitous and oft-used tool, while clickers were cited as a widely promoted technology on each campus. In particular, all groups reported that course websites played a key role in the administration of their courses as well as in their teaching practice. For example, faculty reported that using websites to post course materials (e.g., lecture notes and slides, research articles, course syllabi) both facilitated students' ease of access to these documents while also eliminating the need to photocopy and distribute materials in class. Course websites also are used as a pedagogical tool; some faculty reported utilizing discussion boards to encourage student

Table 1
Instructional Technologies Referenced by Disciplinary Groups

	Math References 18 faculty	**Physics References** 11 faculty	**Biology References** 11 faculty
Animations and video	1	3	1
Calculators	1	0	0
Chalkboard	11	5	2
Clickers	6	10	5
Computer programs	7	1	1
Course websites	3	5	7
Demonstrations	1	8	1
Digital projector	0	0	1
Digital tablet	2	1	2
Misc. objects	1	1	5
Other online resources	1	2	1
Overhead projectors	4	2	1
PowerPoint slides	0	7	7

dialogue and identify misconceptions prior to the next class. This indicates that faculty in each disciplinary group are cognizant of the educational and administrative opportunities represented by online technologies; however, the efficacy with which faculty use blended learning (i.e., the utilization of multiple learning environments) is an open empirical question.

Important variations also existed among groups. For example, math faculty viewed the chalkboard as central to their instructional practice, but it was less referenced by physics and biology faculty. In an observation that underscores the role of cultural convention in tool use, one respondent noted, "I'm a very traditional instructor, so I don't believe in a lot of computer software or heavy use of graphing calculators or fancy slides during class, you know, I'm basically a chalk person." Another respondent noted that mathematics is a "traditional discipline" and that, as a result, she was having difficulty in convincing her colleagues to incorporate lab sessions using the computer program Matlab into a calculus course.

Further underscoring disciplinary variation, faculty in each group reported differences in the number of tools they considered to be part of their local technology resource base. Physics faculty reported the most diverse repertoire of tools, with at least two individuals referencing eight different tools. In contrast, at least two individuals in the math and biology groups referred to six tools, thus indicating a slightly more constrained resource base. This is particularly the case for mathematicians, whose reference to clickers was more about awareness of local pedagogical reforms than actual considerations for using the tool in their classrooms.

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What are the faculty decision-making pathways for using instructional technology?

Faculty do not adopt instructional technologies in an uncritical or automatic fashion but instead subject them to a decision-making process that is influenced by pre-existing beliefs, personal experiences, instructional goals, perceived affordances, and lesson scripts. We identified 59 distinct decision-making pathways related to the use of instructional technology in the classroom. A selection of the most commonly reported pathways are reported in Table 2 (see page 7).

Table 2

Frequently Reported Decision-Making Pathways for Each Disciplinary Group

Decision-Making Pathways	# of References
Math (18 faculty)	
(PA) Chalkboard affords writing formulas/theorems >>> (LS) Regularly writes on chalkboard while also talking/lecturing	9
(PA) Website affords posting of course materials >>> (B) Students benefit from access to materials >>> (LS) Regularly posts homework, lecture notes, and quizzes	5
(G) Keep students from writing notes the entire class >>> (PA) Digital tablets or document cameras afford projecting of pre-written notes >>> (LS) Posts lecture notes on website while writing on them during class	2
(G) Maintain pacing and sense of “flow” in class >>> (PA) Technology would disrupt flow >>> (LS) Uses chalkboard	2
Physics (11 faculty)	
(B) Belief that students learn best in interactive settings >>> (PA) Clickers afford engagement with material >>> (LS) Regularly uses clickers	5
(PA) Website affords posting of course materials >>> (B) Students benefit from access to materials >>> (LS) Regularly posts homework, lecture notes, and quizzes	4
(PA) PowerPoint affords succinct organization of material >>> (B) Beneficial to explain why a topic is important to learn >>> (PE) Learned best as a student this way >>> (LS) Regularly lectures with PowerPoint slides	4
(B) Many students have misconceptions about physics >>> (PA) Demonstrations afford ability to visualize physics principles >>> (LS) Regularly uses demonstrations as launching point for lecture and to address source of misconceptions	3
(PA) Chalkboard affords writing and pace-setting >>> (PA) PowerPoint can make the class move too fast >>> (B) Students learn better with a slower pace >>> (LS) Regularly writes on board and avoids PowerPoint	2
Biology (11 faculty)	
(B) Students learn best while actively engaged in the material >>> (PA) Clickers afford question-posing and are particularly useful in large classes >>> (LS) Regularly uses clickers to engage students and assess conceptual understanding	5
(PA) Website affords posting of course materials >>> (B) Students benefit from access to materials >>> (LS) Regularly posts homework, lecture notes, and quizzes	5
(B) Student learning is facilitated by making connections to the real world >>> (PA) PowerPoint affords projecting of multi-dimensional visuals >>> (LS) Regularly projects complex graphics in class and posts on website	5
(G) Have students appreciate biology >>> (PA) Demonstrations afford ability to demonstrate biological phenomenon >>> (LS) Regularly uses demonstrations and passes around plant material	3

Note: (G) = Goal, (PA) = Perceived affordance, (B) = Belief, (PE) = Personal experience, (LS)= Lesson script.

Math faculty

The reference to chalkboards as a tool that afforded the writing of formulas, theorems, or problem-solving procedures was the most commonly cited pathway for mathematicians. Interestingly, these pathways were not preceded by the articulation of an instructional goal or belief about teaching and learning; they were reported as statements of fact (e.g., "This class is me standing at the board and drawing pictures"). Another commonly reported pathway referred to websites as a tool that enabled the efficient distribution of course materials in an expeditious manner—a practice that was shaped in part by the belief that students benefited from regular access to these materials.

The belief that learning is inhibited when students spend the entire class period writing notes informed the use of digital tables or document cameras in the classroom. Instructors reporting this pathway wrote their lecture notes prior to class, posted them on the course website, and then elaborated on the notes during class by writing directly on them. In this way, the physical writing of formulas or computations was retained but with the added benefit of providing notes to students prior to class for study while also reducing the amount of required note-taking.

Finally, two math faculty noted that they do not use technology because of the perceived disruption to the "flow" of the class. For example, clickers were viewed as taking too much time in class to pose questions and wait for responses and PowerPoint slides facilitated overly rapid instruction while not allowing for hand-written computations. For these respondents, controlling the pace of the class was best achieved by using the chalkboard.

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Physics faculty

For physics faculty, the belief that students learn best in interactive teaching environments, rather than sitting passively in the classroom, was a primary driver behind the use of clicker-response systems. The use of both algorithmic and conceptual questions in undergraduate physics classes also facilitated the use of clickers and chalkboards.

Like the math faculty, physics respondents perceived the benefits of posting materials on course websites. Additionally, PowerPoint slides afforded the opportunity to organize course material succinctly via outlines and rich imagery, which in turn provides motivation for students to learn the material.

Interestingly, respondents noted that concise explanations of why topics are worth learning played a key role in their own learning process and that PowerPoint slides offered an efficient way to accomplish this goal. Physics faculty also noted that demonstrations afforded the ability to visualize physics phenomena in an accessible manner, which provided a good launching point for lectures, and that chalkboard use helped the instructor effectively control the pacing of the class.

Biology faculty

The biology faculty in the study reported that clickers afforded the opportunity to realize their goal of keeping students engaged during class. Clickers also were used as an assessment technique to gauge students' conceptual understanding in real-time. Like the math and physics faculty, the biologists perceived course websites as useful tools for disseminating information. Finally, the belief that using visuals of biology phenomena keeps students engaged and facilitates learning was realized through the use of PowerPoint slides and demonstrations, which were reported as commonly used in class. Slides used in class also were posted on course websites as part of lecture notes.

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These data underscore the fact that the adoption, adaptation, or rejection of technology-based teaching innovations is influenced by alignment among (a) pre-existing faculty beliefs and goals, (b) perceived affordances of particular tools, and (c) cultural conventions in the disciplines.

What instructional technologies are faculty actually using in the classroom?

In examining which technologies faculty use in the classroom, it is important to note that we do not focus on these tools in isolation but as interacting with particular teaching methods and types of student cognitive engagement. This perspective acknowledges that technology use has major implications for the type of instruction that takes place in the classroom.

Data on teaching practices are provided in Table 3 (see page 10). These data represent the proportion of times that a particular code was observed across all of the five-minute intervals that comprise the TDOP instrument.[19] For example, lectures were observed in 75% (or about 286) of the 381 five-minute intervals involving math faculty.

Table 3
Percentage of Five-Minute Intervals in Which Each Instructional Code was Observed Across All Dimensions of Practice, Instructors, and Class Periods

	Mathematics 381 intervals 18 instructors	**Physics** 219 intervals 11 instructors	**Biology** 224 intervals 11 instructors
Dimensions of Practice			
Teaching Techniques			
Lecture	75%	93%	84%
Illustration	7%	13%	18%
Demonstration	1%	40%	0%
Small group discussion	4%	4%	12%
Multimedia	0%	7%	3%
Worked out problems	66%	18%	0%
Desk work	10%	1%	1%
Rhetorical question	11%	5%	4%
Display conceptual question	21%	17%	23%
Display algorithmic question	24%	3%	0%
Comprehensive question	21%	5%	8%
Novel question	8%	3%	9%
Clicker question	0%	13%	9%
Cognitive Engagement			
Receive/Memorize	83%	93%	91%
Problem solving	58%	28%	14%
Creating	6%	11%	14%
Integration	7%	7%	5%
Connections to real world	6%	24%	20%
Instructional Technology			
Chalkboard	75%	48%	7%
PowerPoint	0%	57%	80%
Demonstration equipment	0%	33%	0%
Clickers	0%	13%	9%
Misc. object	3%	11%	3%
Pointer	0%	9%	27%
Digital tablet/Document camera	6%	9%	9%
Overhead projector	8%	12%	6%

Tables 4-6 show data on how the three dimensions of teaching practice (i.e., teaching methods, cognitive engagement, and instructional technology) were observed in conjunction with each other for each five-minute interval. For example, the "triad" of lecture, receive/memorize, and chalkboard were observed being used together by math faculty in 60% of the five-minute intervals across all respondents in the data set.

Table 4

Selected Triadic Affiliations for Mathematics Instructors

Teaching Method	Cognitive Engagement	Instructional Technology	Proportion of Five-Minute Intervals
Lecture	Receive/Memorize	Chalkboard	60%
Worked out problems	Receive/Memorize	Chalkboard	50%
Worked out problems	Problem solving	Chalkboard	39%

Table 5

Selected Triadic Affiliations for Physics Instructors

Teaching Method	Cognitive Engagement	Instructional Technology	Proportion of Five-Minute Intervals
Lecture	Receive/Memorize	Laptop/Slides	51%
Lecture	Receive/Memorize	Chalkboard	46%
Worked out problems	Receive/Memorize	Chalkboard	16%
Worked out problems	Problem solving	Chalkboard	12%
Demonstrations	Receive/Memorize	Demo equipment	28%
Demonstrations	Integration	Demo equipment	3%
Small group work	Problem solving	Laptop/Slides	4%
Small group work	Connections to real world	Laptop/Slides	1%

Table 6

Selected Triadic Affiliations for Physics Instructors

Teaching Method	Cognitive Engagement	Instructional Technology	Proportion of Five-Minute Intervals
Lecture	Receive/Memorize	Laptop/Slides	69%
Lecture	Receive/Memorize	Chalkboard	6%
Small group work	Problem solving	Laptop/Slides	7%
Small group work	Conections to real world	Laptop/Slides	4%

Math faculty

The chalkboard was the most used instructional technology among math faculty, which is entirely consistent with the dominant cultural convention of their discipline. This tool was frequently observed in conjunction with two teaching methods (i.e., lecturing and working out problems) and two types of cognitive engagement (i.e., receive/memorize information and problem-solving).

Only three other tools were observed being used: overhead projectors, digital tablets/document cameras, and miscellaneous objects. As previously noted, some math faculty in our study were experimenting with the use of digital tablets as a way to maintain the cultural convention of working through problems by hand in front of the classroom while minimizing the amount of note-taking for students. Taken together, these data provide a detailed snapshot of how math faculty use instructional technology and other elements of instruction in the classroom.

Physics faculty

In contrast, the data for physics faculty indicate a reliance on a wider range of practices than the math faculty described above. The instructional technologies used by physics faculty included PowerPoint slides, chalkboard, demonstration equipment, overhead projectors, clickers, and laser pointers. In interviews, physics faculty indicated that they used different types of technology not only to keep students engaged but also as a natural outgrowth of the content itself. For example, demonstrations of physical phenomena are a common feature of physics classes. While these tools were observed in conjunction with a variety of teaching methods and cognitive engagement, the most frequently observed practices remain lecturing with PowerPoint slides while students operate in the receive/memorize information mode of engagement.

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Biology faculty

The primary instructional technologies used by biology faculty include PowerPoint slides and laser pointers. In the classroom, these faculty were mostly observed lecturing with slides and indicating key aspects of the slides with the laser pointers while students operated in the receive/memorize information mode of engagement. Less commonly, biology faculty used small group work that involved students in other types of cognitive engagement.

Implications for Policy and Practice

The findings presented in this brief have important implications for those invested in pedagogical reform efforts in math and science education at universities. The goal of the America Competes Act of 2007 to identify promising teaching practices in STEM disciplines is shared by many institutions across the nation, including the University of Wisconsin–Madison, and instructional technology remains a central focus of many of these efforts. Given that faculty use of instructional technology is so closely linked to both instructional goals and student cognitive engagement—two critical factors related to student learning—careful attention should be paid to encouraging the appropriate and effective use of instructional technology in the university classroom.

This study supports the idea that the adoption, adaptation, or rejection of technology-based teaching innovations is influenced by alignment among (a) pre-existing faculty beliefs and goals, (b) perceived affordances of particular tools, and (c) cultural conventions in the disciplines. The practices of math faculty represent a strong case in point as chalkboards are clearly the preferred tool for teaching in the mathematics courses analyzed in this study. The chalkboard is well suited to the instructional goal of visually representing problem-solving models while also having the advantage of being a familiar tool among all mathematicians. As a result, math faculty see little need to adopt new tools that require substantial training or a switch from a style of teaching that they consider useful and natural. Indeed, at one research site in this study, a campus-wide initiative to use clickers gained little traction in the mathematics department due to their perceived lack of utility and the view that its advocates neither understood nor appreciated the work of math faculty.[20]

...[disciplinary] variability suggests that policymakers should not impose institution-wide solutions...

Yet these cultural conventions are not immutable. Some math faculty in our study were experimenting with digital tablets and document cameras; this represents an attempt to maintain the core features of a teaching convention (e.g., actively working through problems in a way that is visible to students) while taking advantage of the features of new technologies. Thus, policymakers and advocates of technology use should first consider existing local practices, and the extent to which they align with proposed innovations, before determining whether they can improve upon them.

The large disciplinary variation in tool use documented in this study also highlights the importance of aligning technology-based innovations with existing disciplinary practice. Such variability suggests that policymakers should not impose institution-wide solutions but instead should focus on the instructional goals and teaching practices associated with specific disciplinary groups.

Notes

[1] By faculty, we mean all people, including graduate students, who hold undergraduate teaching positions (excluding TAs)—whether full- or part-time, tenured or untenured—in postsecondary institutions, except for emeritus faculty and post-docs.

[2] *Classroom response systems*, or clickers, include software that allows instructors to pose multiple-choice questions to students via computer projectors and handheld transmitters that allow students to answer these questions. The instructor's computer collects and analyzes the responses and then displays the results in a bar chart.

[3] For general information about the conceptual and empirical background behind many of these innovations, see National Research Council, *How People Learn: Brain, Mind, Experience and School* (Washington, DC: National Academy Press, 2000). For specific information about Peer Instruction and audience response systems, see Eric Mazur, *Peer Instruction: A User's Manual* (New Jersey: Prentice Hall, 1997), and Douglas Duncan, "Clickers: A New Teaching Aid with Exceptional Promise," *Astronomy Education Review* 5, no. 1 (2006): 70–88. For information about problem-based learning, see Cindy E. Hmelo-Silver, "Problem-Based Learning: What and How Do Students Learn?" *Educational Psychology Review* 16, no. 3 (2004): 235-266. For information about handheld devices, see Jane E. Caldwell, "Clickers in the Large Classroom: Current Research and Best-Practice Tips," *Life Sciences Education* 6, no. 1 (2007): 9–20. For information about distance learning, see Hilary MacQueen and Jeff Thomas, "Teaching Biology at a Distance: Pleasures, Pitfalls, and Possibilities," *American Journal of Distance Education* 23, no. 3 (2009): 139-150.

[4] Ann L. Brown and & Joseph C. Campione, "Guided Discovery in a Community of Learners," in *Classroom Lessons: Integrating Cognitive Theory and Classroom Practice*, ed. Kate McGilly (Cambridge, MA: The MIT Press, 1994).

[5] See Chandra Turpen and Noah Finkelstein, "Not All Interactive Engagement is the Same: Variations in Physics Professors' Implementation of 'Peer Instruction,'" *Physical Review Special Topics: Physics Education Research* 5, no. 2, 020101 (2009): 1-18.

[6] See Liette Lapointe and Suzanne Rivard, "A Multilevel Model of Resistance to Information Technology Implementation," *MIS Quarterly* 29, (2005): 461–491; Michael Molenda and Barbara Bichelmeyer, "Issues and Trends in Instructional Technology: Slow Growth as Economy Recovers," in *Educational Media and Technology Yearbook 2005*, ed. Michael Orey, Jo McClendon, and Robert Maribe Branch (Englewood, CO: Libraries Unlimited, 2005), 30: 3-28.

[7] Everett M. Rogers, *Diffusion of Innovations*, 4th ed. (New York: Simon & Schuster, Inc., 1995). See also James P. Spillane, Brain J. Reiser, and Todd Reimer, "Policy Implementation and Cognition: Reframing and Refocusing Implementation Research." *Review of Educational Research* 72, no. 3 (2002): 387-431

[8] See Fred Davis, "Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology." *MIS Quarterly* 13 (1989): 319–340; Viswanath Venkatesh and Hillol Bala, "Technology Acceptance Model 3 and a Research Agenda on Interventions," *Decision Sciences* 39, no. 2 (2008): 273-315; Peggy A. Ertmer, "Teacher Pedagogical Beliefs: The Final Frontier in our Quest for Technology Integration?" *Educational Technology Research and Development* 53, no. 4 (2005): 25-39.

[9] James Fairweather, *Linking Evidence and Promising Practices in Science, Technology, Engineering, and Mathematics (STEM) Undergraduate Education: A Status Report for the National Academies Research Council Board of Science Education, 2008*, http://www7.nationalacademies.org/bose/Fairweather_CommissionedPaper.pdf

[10] Stephen Hegedus et al., *Scaling up SimCalc Project: Diffusion of a Research-Based Innovation in Terms of Sustainability and Spread* (University of Massachusetts, Dartmouth: Kaput Center for Research and Innovation in STEM Education, 2009).

[11] Sandy K. Piderit, "Rethinking Resistance and Recognizing Ambivalence: A Multidimensional View of Attitudes Toward an Organizational Change," *Academy of Management Review* 25 no. 4 (2000): 783-794.

[12] Joan S. Stark, "Planning Introductory College Courses: Content, Context, and Form," *Instructional Science* 28 (2000): 413-438; Robert J. Menges, "Shortcomings of Research on Evaluating and Improving Teaching in Higher Education," *New Directions for Teaching and Learning* 83 (2000): 5-11.

[13] See James P. Spillane, Richard Halverson, and John B. Diamond, "Towards a Theory of School Leadership Practice: Implications of a Distributed Perspective," *Journal of Curriculum Studies* 36, no.1 (2001): 3-34. While these studies focus on school leadership, the basic premise of the distributed nature of educational work also applies to classroom teaching.

[14] See Richard Halverson, "Systems of Practice: How Leaders Use Artifacts to Create Professional Community in Schools," *Educational Policy Analysis Archives* 11, no. 37 (2003): p. 2.

[15] See Richard J. Shavelson and Paula Stern, "Research on Teachers' Pedagogical Thoughts, Judgments, Decisions and Behavior," *Review of Educational Research* 51, no. 4 (1981): 455-498; Alan H. Schoenfeld, "Models of the Teaching Process," *Journal of Mathematical Behavior* 18, no. 3 (1998): 243-261; and Joan S. Stark, "Planning Introductory College Courses: Content, Context and Form," *Instructional Science* 28 (2000): 413-438.

[16] See James G. Greeno, "Gibson's Affordances," *Psychological Review* 101, no. 2 (1994): 236-342; Donald Norman, *The Design of Everyday Things* (New York: Doubleday Business, 1990). The concept of perceived affordances and its relationship to activity is also remarkably similar to the focus on how users perceive the potential utility of a technology in research using the Technology Acceptance Model of Venkatesh and Bala (2008).

[17] Matthew T. Hora, *Applying Insights From Faculty Teaching Practices to Science and Math Education Reforms*, WISCAPE Policy Brief, (Madison, WI: University of Wisconsin–Madison, Wisconsin Center for the Advancement of Postsecondary Education, 2011).

[18] NSF award #: DRL-0814724. For more information about the CCHER study, visit http://ccher.wceruw.org

[19] A typical 50-minute class would have 10 five-minute intervals worth of data per respondent.

[20] For more on this point, see Charles Henderson and Melissa H. Dancy, "Physics Faculty and Educational Researchers: Divergent Expectations as Barriers to the Diffusion of Innovations," *American Journal of Physics* 76, no. 1 (2008): 79-91.

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