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A SOCIOCULTURAL INTERPRETATION OF THE EFFECTS OF AUDIENCE RESPONSE SYSTEMS IN HIGHER EDUCATION

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Introduction

Audience response systems have been in use for several years in higher education and have shown promise for transforming classroom participation and learning, especially in the sciences. These systems enable students to respond to instructor questions using small handheld devices that employ infrared technology to communicate data to a central computer. Instructors can then display a histogram of student responses and use this display to discuss students' answers or to adjust their instruction on the basis of students' level of understanding.

Because they are mature technologies, there has been a considerable amount of research on their effects. In a review of research conducted in 2003 by a team of researchers here at SRI, we identified 25 studies that examined effects of audience response systems (Roschelle, Abrahamson, & Penuel, 2003; Roschelle, Penuel, & Abrahamson, 2004). Of these studies, fifteen reported positive effects of using the systems on student engagement. Ten studies reported positive effects on students' understanding of complex subject matter in subjects ranging from physics to elementary level reading. For example, analysis of results from multiple large lecture classes conducted at different universities using Peer Instruction, a teaching method often used in conjunction with audience response systems, indicated that gains of students in peer instruction classrooms on the Force Concept Inventory, a widely used test of students' understanding of the most basic concepts of Newtonian mechanics were much higher than for students in regular lecture classes (Crouch & Mazur, 2001; Hake, 1998).

There are gaps, however, in systematically measuring and understanding how teaching and learning unfolds in these kinds of networked classrooms (Roschelle et al., 2004). For example, none of the studies that have examined the effects of systems have also sought to measure systematically the contribution of specific pedagogical elements to the effects. Also, some of the more dominant theories and ideas about how instruction in higher education with audience response systems unfolds do not adequately capture the range of experiences reported by practitioners. These are major gaps in the knowledge base guiding research and development in the area of audience response systems, since systematic data on instruction and its effects are both necessary to guide improvements in the classroom and to test prevailing explanations of the effects.

A central explanation for the effectiveness of teaching with audience response systems focuses on the role that systems use plays in facilitating conceptual change. We describe that account, before considering some of the common experiences of instructors and students in classrooms where audience response systems are used that the account fails to consider in theorizing the effects that have been reported in the literature. We then turn to an examination of how sociocultural theory, which has been used to describe learning processes within networked classrooms at the K-12 level, might be used productively to theorize teaching and learning in higher education settings with audience response systems.

The Conceptual Change Account

More commonly, the research on audience response systems focuses on explaining how teaching with the systems helps bring about conceptual change in students. Conceptual change has been of central interest to researchers in cognitive science, because it is an enduring challenge for educators (National Research Council, 1999). Students tend to bring many conceptions of scientific domains to class from their lived experience that do not match scientists' understanding of those concepts; those conceptions have proven quite difficult to change, especially without involving students in collaboratively constructing their understandings of concepts in such a way that reveals the underpinnings of concepts and shortcomings in their own thinking (Roschelle, 1996). The promise of audience response systems in facilitating conceptual change is therefore of central importance to the science education community, because any instructional approach that might improve the odds students will give up their own misconceptions and develop more scientific understandings of concepts is of great value to the field.

A recent paper by Judson and Sawada (2002) provides a synthesis of arguments that focus on theorizing how conceptual change comes about. These authors, in reviewing research conducted since the 1960s on different generations of audience response systems, argue that in the past twenty years, much more attention has been paid to how systems foster student-to-student interaction, a theme that is also echoed in the communication account described above. But they argue that the significance of the interaction derives from constructivist learning theory, which in their words has "highlighted the importance of collaborative discourse that allows students to negotiate meaning in science and mathematics classes" (Judson & Sawada, 2002, p. 173).

Discussion, the authors note, does not inhere in the technology, but must be orchestrated by the instructor in conjunction with use of the audience response system. Discussion can take place after students have seen a question posed by the instructor but before answering, or as in Peer Instruction, it can take place once students have answered and seen a display of their answers that indicates wide divergence in responses (see Mazur, 1997). As part of the discussion, students are often encouraged to explain their answers to peers or to the whole class and listen to counter-arguments to their own position (Abrahamson, 1999; Dufresne, Gerace, Leonard, Mestre, & Wenk, 1996).

As we have noted elsewhere (Roschelle et al., 2003), there are close parallels between the emphasis placed on class discussion and debate and ideas from cognitive science about how best to promote conceptual change. In particular, research on self-explanation (Chi, 1996) suggests that in formulating arguments and presenting them to others, students come to a deeper understanding of concepts. Working together with a peer, moreover, can help students to converge on meanings of concepts that more closely resemble those of target understandings in a domain, even if students' discourse does not closely resemble the way scientists might talk about concepts (Roschelle, 1992).

The conceptual change account also emphasizes that the nature of questioning is particularly important to effective uses of audience response systems (Dufresne et al., 1996; Poulis, Massen, Robens, & Gilbert, 1998; Shapiro, 1997). Questions that target the core concepts of a discipline are believed to be most effective in promoting conceptual change, especially when answer

choices reflect common student conceptions that may diverge from target understandings. Eliciting those misconceptions is believed to be particularly important—even necessary—step in the development of scientific concepts, especially because the meanings of words and concepts in everyday settings is often quite different from meanings in the specialized languages of science (Gee, 1999; Lemke, 1990; Vygotsky, 1987).

Judson and Secada (2002) suggest that these pedagogical elements are what make the use of audience response systems effective. They note that earlier research from the 1960s on such systems—in which instructors used systems to achieve behavioral objectives—found few positive effects on achievement. By contrast, more contemporary uses have shown much more promise with respect to improving achievement, leading them to conclude

> It is more beneficial for the student, who has just arrived at a new conceptual understanding, to explain to peers how he/she struggled and arrived at his/her new rationale than it is for an instructor to simply explain the abstraction. (Judson & Sawada, 2002. p. 178)

Missing Experiences from the Conceptual Change Account

The conceptual change account provides several important insights into what works about teaching with audience response systems. In fact, evidence from studies of Peer Instruction suggests conceptual change does happen in classrooms where audience response systems support its use (Crouch & Mazur, 2001). Moreover, the kinds of questioning, discussion, and other interactive pedagogies cited in the conceptual change account have been reported by practitioners in the field, and as we have argued elsewhere they are consistent with a number of findings from the learning sciences about how people learn (Roschelle et al., 2003). However, there are several aspects of instructors' and students' reported experiences of being in classrooms where audience response systems are used that are not captured fully by either the communication or conceptual change account. These experiences are reported primarily in research conducted by scholar-practitioners familiar with the use of the system; and more recently, large-scale survey results have replicated some of their findings. These findings are consistent enough to warrant a careful consideration and re-interpretation of the theories that are necessary to explaining the effects of teaching with audience response systems.

One such experience is that early in students' encounters in classrooms where audience response systems are used, students adjust their participation in class to the changed classroom environment, often with mixed feelings. Research by Jackson and Trees (2003) examined the perception of some 1,500 students enrolled in University of Colorado classes that used response system technology indicated that many students were anxious about the heightened accountability for learning in networked classrooms. They also found that students who had taken many lecture classes in the past were less positive about the technology, perhaps because they had already developed some strategies for participating in large lecture classes.

Jackson and Trees' study also revealed that although the use of audience response systems increased class attendance, many students felt ambivalent about this effect. Students who were coming to class for the first time tended to be disruptive; many resented that participation in class could be more accurately measured by the response systems. Students who already attended lecture classes willingly resented the disruption caused by the students who came to class less often.

Experts in teaching with the systems acknowledge these challenges in outlining a set of recommendations for how instructors should address them. In his seminal book on teaching with audience response systems, *Peer Instruction*, Mazur writes that it is particularly important for instructors to be prepared for student resistance when audience response systems and interactive pedagogies are introduced into the large lecture:

> Students are not likely to accept a change in lecture format with open arms. They are used to traditional lectures and will doubt the new format will help them achieve more (i.e., obtain a higher grade in the course). Since full student collaboration is essential to the success of the *Peer Instruction* method, it is important to motivate students early on. (Mazur, 1997, p. 19)

Mazur's warning is similar to that of Duncan, another higher education user of audience response systems:

> Especially in a large university class, students have certain expectations: They will be relatively anonymous; they should sit up front and sometimes raise their hands if they want to be noticed; they should sit in the back of the lecture hall if they want to catch up on homework or read a newspaper; if a lecture doesn't seem it will be worthwhile, they should just stay home—no one will notice, and they aren't graded just for showing up in class. The use of a clicker system shatters these student expectations." (Duncan, 2005, p. 21)

An additional shortcoming of the conceptual change account is that it has not sought to explain the emergence of strong feelings among students that the classroom environment as a whole has become one in which it is safe to pose questions and admit difficulties of understanding. Abrahamson and colleagues (Abrahamson, Owens, Demana, Meagher, & Herman, 2003), for example, reported that before the introduction of Texas Instruments' Navigator system into their classrooms (a specific kind of audience response system with advanced affordances for interaction), students reported that they would rarely admit in class or even to the teacher when they were having problems understanding the subject matter. They feared that others would think that they were stupid, or that they were the only students having problem. After Navigator became part of the classroom, however, the environment transformed for students, and they began to feel much safer taking risks of admitting that they did not understand something. The public, anonymous display gave them and their teacher immediate knowledge of different class positions. Students came to see that others had the same difficulties that they did, opening the way for class discussion where reasons for actions taken become more important than who took them. The following exchange among students in a focus group, reported in Owens et al. (2002) illustrates how many students experienced the class:

> **S1**: … whereas in just a regular classroom setting, when the teacher asks, "Does everyone get this material?" And then you look around and everyone is nodding their head, "Yes!" You don't want to be the one that said, "Well no, actually. I don't get it at all! So can you explain to me?" And waste everybody else's time.
>
> **S2**: That is right! That is so true!
>
> **S1**: … without the system you'd feel more I guess ... alone -
>
> **S2**: Unsure!
>
> **S1**: Yeah! You're not ... as with the Navigator you're more of a group and you know what everybody else is thinking ... what their answer is.

No new class starts off with such feelings present and many probably never develop them, but classrooms with audience response systems seem naturally to evolve in this direction. Whether it happens more or less in networked classrooms than in regular lectures has not yet been proven at the level of a randomized study, but there is strong circumstantial evidence that it is so. We take up one possible set of hypotheses as to why this is so in the next section.

Toward a Sociocultural Theory of Audience Response Systems

A more complete theory is needed to explain the diverse experiences of students and instructors in classrooms with audience response systems, which accomplishes three things:

- Accounts for how changes in interactions cause students and instructors to adjust their own participation in class;
- Accounts for the emergence of new classroom-level dynamics from changed interactions and individual orientation; and
- Maintains a focus on communication and individual learning as evident from changes to intent participation in class.

In this section, we consider how three different sets of ideas from sociocultural theory can help account for the phenomena reported in research on audience response systems: (1) the idea that learning is a process of transformation of participation in cultural activities that are themselves changing; (2) the idea that learning science involves developing fluency with the forms of talk associated with doing science; and (3) the idea that motivation and interest emerge from particular patterns of social interaction and from engagement with tasks that have particular kinds of features.

We are drawn to sociocultural theory for an account of audience response systems, because research on classroom network technologies with a different set of affordances—for classroom simulations, for example—has turned to sociocultural ideas about learning and development. For example, Stroup and colleagues (Stroup, 2002; Stroup et al., 2002) have drawn on Vygotsky's ideas (Vygotsky, 1987; Wertsch, 1979) about *dynamic structuring* of activities to describe how mathematical ideas structure the social space of network-supported learning activities aimed at teaching students about parametric space. Similarly, Kaput and Hegedus (2002) have sought to explain dynamics in such classrooms with reference to students' identification with mathematical projections; their notion of identification bears a close kinship with sociocultural accounts of identity as formed in the context of activity and mediated by culturally-situated tools (Penuel & Wertsch, 1995b).

In the next section, we review in greater detail some of the potentially relevant aspects of sociocultural theory to informing a theoretical perspective on the use of audience response systems to support science learning in higher education settings. In this section of the paper, we draw on some examples from K-12 settings, but the primary emphasis is on explaining phenomena that are also typically associated with use of audience response systems in higher education.

Learning as a Process of Transformation of Participation

Contemporary sociocultural theories define learning and development as a process of *transforming participation in valued sociocultural activities* (Rogoff, 1995, 2003; Rogoff, Baker-Sennett, Lacasa, & Goldsmith, 1995). Rather than viewing knowledge as a fixed entity that must be transmitted from instructor to students, sociocultural theorists emphasize that people learn when given opportunities to practice using the tools of a discipline—including its discourse, methods, and technological instruments that aid discovery—under conditions in which they can be guided by experts who are either more capable peers or adults (Rogoff, 1990; Vygotsky, 1978; Wertsch, 1979, 1991). Over time, as learners gain experience with particular tools and become familiar with participation in particular cultural activities such as those of an academic discipline, their participation transforms from one in which they play primarily peripheral roles with limited responsibility to fuller roles with more responsibility for the activity (Lave & Wenger, 1991). Of particular significance, too, in sociocultural theory is a distinction made between *intent* and *passive* participation, which captures two different ways that learners listen in and pay attention to cultural activities (Rogoff, Paradise, Arauz, Correa-Chavez, & Angelillo, 2003). Learners tend to participate and observe activities more intently when they are preparing to participate in them; more passive participation is more common, however, in instructional settings in which learners are not expected to take on more responsibility for full participation in the activity. Despite the fact that many instructional settings offer few such opportunities for students, sociocultural researchers have shown that those settings that do allow learners' participation to transform are quite effective with a wide range of students (Doherty, Hilberg, Pinal, & Tharp, 2003; Tharp & Gallimore, 1988).

At the same time that individuals' participation changes over time, their own contributions and the kinds of interactions that take place within activities transform those activities themselves (Rogoff, 1995; Rogoff et al., 1995). Individual, interpersonal, and community development are intertwined, and become the focus of sociocultural accounts of development:

> …[H]uman development is a process of people's changing participation in sociocultural activities of their communities….Rather than individual development being influenced by (and influencing) culture, from my perspective, people develop as they participate in and contribute to cultural activities that themselves develop with the involvement of people in successive generations. (Rogoff, 2003, p. 52)

Rogoff's perspective is that the account makes room for examining these activities from what she calls community, interpersonal, and personal (individual) "planes." Her perspective is that these planes are mutually constitutive (Rogoff, et al., 1995b); they do not exist apart from one another but are separable in principle for the purpose of developmental analysis, like lenses that can have a different focus depending on the analyst's purpose.

When attention is directed to a particular plane, Rogoff emphasizes that different kinds of learning processes come into focus (Rogoff, 1995a; 1995b). At the personal plane, analysts focus on how it is that individuals change and transform as they participate in activity and how they orient themselves—as active, passive, or even avoidant—to participation. At the interpersonal plane, analysts examine what people are doing together, and examine how people come to understand each other and structure participation for each other. And at the

community plane, analysts examine the way that people apprentice to larger cultural practices, like becoming a instructor or learning to use scientific discourse.

By itself, Rogoff's theory provide just a broad outline of what is needed to understand in order to develop a more coherent theory of what is happening in classrooms with audience response systems to produce the kinds of transformations that are claimed for them. We need to take into account the research on the personal, psychological processes typically activated in classrooms with audience response systems—engagement, motivation, and shyness for example—in considering how these systems might change individuals' participation in classroom activities. And we need to take into account what is known about the role of feedback and group participation, processes highlighted in the cognitive account, in considering how participation is guided differently in classrooms with audience response systems. With this new set of lenses, however, we can also develop hypotheses about the "missing experiences" in the conceptual change account, such as the emergence of classroom community and the experience of disruption often felt by instructors and students when audience response systems are first introduced.

Mediated Action in Sociocultural Theory: Learning to 'Talk Science'

Sociocultural theory that draws on Vygotsky's theory emphasizes the special role of language and other symbol systems in mediating cultural activities. Wertsch (1991; 1998) in particular has argued that the proper unit of analysis for sociocultural research is *mediated action*; by making this claim, he is suggesting that sociocultural research should describe human mental functioning and development in the context of action that is mediated by or performed by cultural tools that are available within particular historical, cultural, and institutional contexts. The cultural tools that are typically analyzed in sociocultural research include language, signs, and other symbol systems, which were given special attention within Vygotsky's account of human development (Wertsch, 1991). In Vygotsky's view, language was an important advance in human evolution, in that enabled us to create "tools" for manipulating not just objects in the world but for creating and adapting ideas and systems of ideas (Vygotsky, 1987).

Sociocultural theorists have paid particularly close attention to the role of symbolic representation and discourse in science. For example, Martin (Martin, 1989) has analyzed the grammars of scientific texts, drawing attention to the way that factual writing in science makes heavy use of nominalizations in describing complex and often abstract processes, which are often subjects of sentences instead of the human agents who performed the scientific work (see also Hanania & Akhtar, 1985; Rodman, 1994). These grammars, argue sociocultural theorists of science, have the effect of placing distance between the activity of doing science and the scientific communities that conduct it (Gee, 1999; Latour & Woolgar, 1986). In fact, engaging in science and writing scientific texts are fundamentally social activities, and doing them successfully depends on access to and fluency with the instruments, methodologies, and languages of science (Bazerman, 1983; Dunbar, 1995; Latour & Woolgar, 1986; Lynch, 1985).

Sociocultural theorists in education have sought to explore the implications of how scientific activity is mediated by language for the study and design of classroom learning environments. Several Australian researchers, for example, have developed and studied strategies for teaching students how to write in the genres of science and he has encouraged teachers to help students recognize when different genres for writing are appropriate and more or less

powerful for purposes of persuading others (Cope & Kalantzis, 1993; Halliday & Martin, 1993). Lemke (1990) has noted that in classrooms where students successfully learn to "talk science," teachers model scientific forms of oral and written language by tending to avoid colloquial, emotive, and figurative language. At the same time, Lemke notes that typical question-posing patterns of teachers in science classrooms, in which the teacher asks students to respond to a question in which the answer is known already, provides students with limited opportunity to develop and elaborate on their understanding of concepts. More extended turns at discourse at generating answers to more open-ended inquiry and practice with inquiry methods may be necessary to promote deeper learning of science concepts (Gee, 2004; Wells, 1993). In addition, students' everyday understanding and language for describing particular constructs is often at odds with scientific ways of speaking, so expanding participation of students in science is likely to require providing students with opportunities to connect everyday concepts to scientific concepts (Gee, 1994; Rosebery, Warren, & Conant, 1992).

Research on students' practice with the academic languages of science by sociocultural theorists provides a bridge to the conceptual change account, which emphasizes strongly the role of discussion in promoting student learning and engagement. Its attention to communicative processes in the classroom and their role in conceptual development highlight the important ways to foster participation in classrooms. In emphasizing the forms of science talk that students need to learn, the sociocultural approach shows how conceptual learning and representing what one knows in speech and in print are inextricably linked.

Sociocultural Accounts of Interest and Motivation

From a sociocultural perspective, interest and motivation are not simply mental states or orientation of individuals, but rather are orientations to action that arise from interactions in particular contexts (Hickey & McCaslin, 2001; Hidi, Renninger, & Krapp, 2004; Jarvella & Volet, 2001; Pressick-Kilborn & Walker, 2002). Just as Vygotsky argues that mental functioning in general is a transformation of social activity (Wertsch, 1979), sociocultural theorists argue that motivation in particular involves a kind of "transformative internalization" of activity and subsequent "externalization" of mental functioning in activity (Walker, Pressick-Kilborn, Arnold, & Sainsbury, 2004). To analyze motivation, then, researchers need to examine more than individuals' mental states and goals but to conduct such an analysis in the context of how states and goals emerge from classroom interactions, features of particular tasks, and other features of the sociocultural context (Rueda & Moll, 1994).

Like motivational theorists who have focused on the goal orientation of individuals for academic tasks (e.g., Ames & Archer, 1988), sociocultural theorists are interested in aspects of motivation that persist beyond individual situations for learning. But rather than focus on motivational goals, sociocultural theorists are more likely to study how individuals enact and display particular identities in the classroom through their participation in learning activities (Gee, 2000-2001; McCaslin & Hickey, 2001; Penuel & Wertsch, 1995b). The identities that are enacted draw upon available and typical forms of self-representation and participation in learning associated with being a member of particular kinds of communities; some of these communities are related to ethnicity and gender, but other categories (e.g., one's status as a "jock" or "burnout") are often relevant to explaining how and why people participate in some learning activities but not others (Eckert, 1989; Heath & McLaughlin, 1993; Penuel & Wertsch, 1995a). Identities tend to have several "externalizing" markers associated with them – forms of speech, dress, even body position in class – that enable one to infer when they are being enacted as part of a particular activity (Gee, 2000-2001; Shaw, 1994). Analyzing the development of identity in classrooms is an important focus of sociocultural research, because its development and disciplinary learning often go hand-in-hand (Wortham, 2004).

Of particular interest to both sociocultural researchers and other motivation researchers are ways in which specific task features contribute to the development of interest and development of motivational orientations (Butler, 1987; Butler & Neuman, 1995; Hackman & Oldham, 1980; McCaslin & Hickey, 2001). Characteristics of tasks that are particularly important for shaping interest and motivation include the kinds of opportunities they afford for student collaboration, the incentives for participation, processes for teacher-student feedback, and rewards and punishments for performance that are associated with particular academic tasks. Learners' perceptions of task features have been shown in motivation research to influence students' motivational goals (Butler, 1987) and also to influence their willingness to participate actively in classroom discussions (Wortham, 2004).

A sociocultural perspective on interest, motivation, and identity can help explain why research studies often report on such dramatic shifts toward increased class participation in classrooms in which audience response systems are used. Just as important, its focus on identity as a lens for examining classroom participation enables us to make hypotheses about how different kinds of students might respond to the introduction of audience response systems. Third, its

attention to the way particular task features contribute to the development of interests and goals among students can help identify what kinds of pedagogical uses of systems are likely to produce the positive effects in the literature, and which uses might yield less positive results. In the next part of this section, we consider in greater detail how sociocultural accounts of motivation, mediated action, and participation can contribute to a more complete model of teaching with audience response system technology.

Initial Hypotheses for a Sociocultural Account of Teaching with Audience Response Systems

Sociocultural theory can help us to generate some new hypotheses about when, how, and why audience response systems are effective, which can then be tested in future research. We can use Rogoff's theory of learning as transformation of participation can help to *when* systems are effective to generate hypotheses about how changes in the personal, interpersonal, and community planes interact to produce a typical classroom trajectory of use and development. We can use sociocultural theories about the importance of learning to "talk science" to help explain *how* audience response systems might produce gains through peer discussion. Finally, we can use a sociocultural theory of motivation to help explain *why* students' engagement is often so strong and also why not all students might respond in the same way to the introduction of audience response systems.

When response systems are first introduced into a classroom, the most apparent change is at the interpersonal plane of development. These systems introduce new system of feedback between instructors and students, which makes it possible for instructors to pose questions of all students (not just a select few) and to get information on how all students are learning. The interaction is mediated by technology, and not performed simply by oral turn-taking. On the personal or psychological plane, this change leads to a set of initial responses on the part of instructors and students. Students form differing reactions to the change—excitement, anxiety, even resistance—to the extent that they recognize and are comfortable with their new roles in the classroom. Instructors, for their part, may realize that the questions they pose and their strategies for addressing student misconceptions must change.

The introduction of the technological display into the classroom has the possibility for creating a range of effects. If instructors display a histogram of results to students, for example, instructors may feel a new kind of pressure to re-teach a concept that few students understand, rather than just the pressure to "move on" to be able to cover more material. At the community plane, we hypothesize that instructors' and students' personal responses leads to what is often experienced as a kind of initial sense that something is awry in how the classroom is flowing. If instructors and students were surveyed about how they think the class is going in the first few weeks after audience response systems are introduced, we would predict that they would in fact say things are not going too well; the majority might even say that things are not going so well, and the instructor would report feeling thrown off-balance by the introduction of the system.

Some instructors and students may be especially challenged by the requirement to discuss their ideas with peers, if this pedagogical strategy is used in conjunction with audience response systems. Sociocultural theory, however, would hypothesize that peer discussion is a critical component of audience response systems, because it gives students an extended turn

at talk with another student that allows them to elaborate on their understanding of a construct. We would also hypothesize, however, that instructors will have limited access to all the peer-to-peer conversations that take place, especially in a large classroom, because they cannot listen in simultaneously to multiple conversations. Audience response systems do facilitate students' developing scientific ways of talking about concepts, but whole-class interaction and discussion of selected student explanations may still be very important to advancing conceptual change, because in such a setting instructors can provide students with guidance about terminology, forms of speech, and ways of thinking that the particular scientific discipline expects its experts to adopt.

At this point, two kinds of interpersonal interactions in the classroom are required for the kinds of participation patterns reported in the literature to emerge. For their part, instructors must demonstrate by their actions that in fact they *do* adjust their teaching strategies or extend their coverage of particular content when students do not understand the material. Instructors' different response changes the typical sequence of tasks students encounter in the classroom--from responding to instructors' questions, having their individual answer evaluated publicly, and then observing as the class moves on—to enable all students to respond to instructor questions, having aggregate answers answered publicly, and pausing for discussion or re-teaching. In this new task structure, students do not have to "perform" their intelligence for others; rather they are able to take risks to indicate what they think, knowing that others will not see their answer and appreciating that the instructor will take the situation seriously if too few students understand the concept to move on. Students, for their part, must take some risks publicly, specifically by sharing their own thinking in peer and whole-class discussion. In such a context, there is no doubt that students are still performing their classroom identities, but the emerging atmosphere of instructor responsiveness is likely to make such risk-taking more palatable and also to change students' perceptions about the kinds of "performances" that are desired in the classroom. Ideally, at this point, students are expected to "show their thinking" in whatever state of formation it is in, rather than "show their smarts" by providing the correct answer.

As both students and instructors become more familiar with their new expected roles and responsibilities for participation within these task structures, new forms of motivation and interest are likely to emerge. Many students become excited about the new approach, and develop a strong interest in participating in class and in using the audience response systems. Instructors, in turn, develop more comfort with using the system and become more confident in its benefits because they see that many students are interested. It is likely at this point, however, that students whose classroom identities do not mesh well with the new roles and responsibilities will not perceive audience response systems or the classroom in such a positive light. At this point, for example, students who are motivated by the idea of demonstrating their knowledge to the instructor by raising their hands early may feel thwarted in their efforts to project an identity as the "smart student." Similarly, students of all ability levels who prefer to "lay low" in the classroom may find the requirement to provide an answer to all instructor questions and discuss those answers with a peer may feel quite threatened by the use of student response systems. Students whose family and cultural backgrounds have communication styles and attitudes toward school participation that differ from the new requirements may also find the new forms of classroom interaction problematic. There is at present too little research on students' interest and motivation conducted in the middle of a

semester or school year to make specific predictions about how particular classroom and cultural identities are likely to influence students' motivation, engagement, and participation, but we would hypothesize that divergence of viewpoints about the benefits of audience response systems is likely to be greatest mid-term or mid-year.

Toward the end of the school year, repeated instances of interaction with the system, as well as the emerging positive affect toward system use by the majority of students and instructors leads to the emerge of a new kind of classroom when viewed from the community plane. Students' increased interest in and motivation for classroom learning helps explain why researchers report increased cognitive engagement and classroom participation by the end of a semester or year. Instructors' own experiences of success with the system and with fostering student engagement lead them to evaluate the experience positively as well, as conferring benefits to them as instructors (improved feedback on learning) and to students (improved conceptual understanding). Third, to the extent that instructors and students have been able to establish a common language for coordinating their efforts (Rogoff, 2003) at producing classroom-wide learning, a positive, new classroom culture focused on learning tends to emerge of the kind reported so widely in the research on audience response systems.

There emerges in such classrooms by the end of class a sense of learning as a shared endeavor among students and the instructor. As one student described it, "We're all kind of in the same boat!" (Owens et al., 2002). It is easy to underestimate the significance of such a remark, and dismiss it as a cliché, because of the way it is expressed. But it masks a sentiment rare in education because it refers to a transformed classroom environment including all the students and the instructor as well. One instructor expressed a sentiment similar to the student's above, in noting that the shared display of student responses enabled by the audience response system gives yields a situation in which students and teachers are *looking together* at the problem of learning, often for the first time:

> [I]t's in the sense that we're all looking at it together for the first time so it's not that, "I've graded them," and, "I know what they've done," and, "I'm giving it back," and, "I'm going over it." With Navigator, we're basically all seeing the information *together* for the first time, and that ... it does … it's hard to explain how it does it, but it's like, "Oh well, look at that, this is something!!!… and um, so we're kind of exploring concepts and ideas together.

Testing the Sociocultural Account: Implications for Further Research

A sociocultural re-interpretation of the phenomenon of audience response systems in higher education has several important implications for how research should be conducted in these settings to examine both implementation and effects. To test the hypotheses identified above, it is necessary to use the theory to specify the kinds of variables that are important to measure and to identify critical points in the developmental trajectory to observe transformations in participation. In this last section of this chapter, we argue that future research on audience response systems should consider collecting data at multiple points in time on student-instructor interaction, instructor and student perceptions of the classroom environment, and teaching and learning outcomes, to advance knowledge of how, when, and why audience response systems can improve teaching and learning outcomes.

Most studies of audience response systems to date have measured two kinds of variables: perceptions of the classroom (from instructors and students) and student learning outcomes. Both perceptions of the environment and measures of learning are still important in a sociocultural account, but they are not adequate to a full account of teaching within the networked classroom. A few studies have sought to *describe* and *interpret* the typical implementation trajectory in classrooms when response systems are introduced, but we are not aware of any that have sought systematically to *measure* aspects of implementation, especially student-teacher interactions. We do believe it is important to measure teacher and student perceptions, but it is just as important to produce systematic analyses of classroom interactions, whether through an analysis of discourse, systematic observation, or review of instructional logs provided by teachers. Such analyses, which could include both quantitative and qualitative measures of classroom practice, are necessary to account for changes in perception of the classroom environment by students and teachers. In addition, it is necessary to measure student motivation and interest more systematically, using measures from psychology (e.g., Midgley et al., 2000), and in conjunction with analyses of classroom interaction. A sociocultural account would specifically seek to use these kinds of measures of individual functioning and social interaction together develop an understanding of how particular patterns of interaction lead to changes in student interest and motivation, and how they activate and potentially transform students' classroom identities.

Testing the adequacy of the sociocultural account for explaining the pattern of results often reported in classrooms that use audience response systems requires some adjustments be made to the typical course of evaluation research. A common evaluation research design measures key variables of interest only at the beginning and end of a study. Our theory, however, specifies at least four different points in time when it would be important to analyze interactions and measure individual mental functioning. Baseline data on student understanding of key concepts, motivational goals, and expectations for the course are important to collect before the class actually begins. When systems are first introduced, it is important to measure initial changes to students' motivation and interest and students' and instructors' perceptions of the classroom environment. After an initial period of novelty has passed, it is particularly critical to examine student-instructor interaction, to see if in fact instructors are adjusting instruction on the basis of what they learn from querying students more often about their knowledge and if students are taking more risks by discussing their thinking and ideas—however tentative—in class with peers and in whole-group interactions.

Toward the end of class, it is important to measure what students have learned, to gather data again on their interest and motivation, and to survey them again on their overall perceptions of the classroom environment.

Theory-testing research also requires rigorous research designs. Ideally, studies that would gather data from such a wide range of data and at multiple time points would also employ research designs that employ either random assignment or use matched control groups. We recognize that budgets for research and evaluation studies rarely afford opportunities to measure both implementation and outcomes or to employ random assignment. However, future investment in audience response systems and the advancement of knowledge of effective teaching in the networked classroom is likely to depend on the field generating a few rigorous studies that can demonstrate impact and account for the impact through documented changes to teaching with audience response systems.

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