The role of classrooms in educational technology research: An example

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Introduction

This paper presents the past and future perspectives on classroom-based *hypermodel* research and the rationales that lie therein. The hypermodel is a new kind of instructional technology that blends aspects of models and hypermedia. GenScope□ and BioLogica□ are instances of the hypermodel, both of which are designed to support the teaching of high school science.[1] GenScope, a first generation hypermodel, is an open-ended inquiry program that presents related models of genetic phenomena which students can use to solve genetics puzzles (Horwitz, 1996). BioLogica, a second generation hypermodel, extends the manipulable nature of the GenScope environment with a scripting functionality, which allows us to design degrees of inquiry support and guidance on a task-by-task basis. The perceived design need for BioLogica is grounded in our work with GenScope. Specifically, we noticed that, by and large, students do not take advantage of the open-ended nature of the learning environment (Horwitz & Christie, 2000).

Historical perspective

GenScope introduced a new paradigm for educational technology, one that bridges the gap between the physical world and a model that represents that it; between the "facts and figures" offered us by the natural world and the mental associations we construct to explain them

(Horwitz, 1996). It was hypothesized that hypermodels might change the learning experience such that an experimental test group could outperform a control group by demonstrating increased levels of learning (after replacing the science textbook with GenScope). This theoretical expectation stems from historical knowledges in education, generally and in science education specifically.

Generally speaking, deep cultural changes are often induced by the introduction of technological advances in society. For example, the introduction of literacy, and practices associated with it, fundamentally changed ways of learning and knowing in primary oral cultures (Ong, 1982). Moreover, universal schooling itself was an outgrowth of the printing press and the resulting widespread premium placed on literacy (Eisenstein, 1979; Postman, 1982). We hypothesized that the development of hands-on learning technologies would slowly change the face of education.

With regard to science education, we had hoped to mediate multilevel thinking, which is one of the largest barriers to deep comprehension. For many students of science, it is difficult to think about how things we can see (effect) connect with things we can't see (cause) (Johnstone, 1991). The traditional textbook approach to science learning primarily gives students information and asks them to think deductively by reasoning from cause-to-effect. Yet research on classical genetics problem-solving has shown that scientists learn through inductive thinking or by reasoning from effect-to-cause (Stewart, Hafner, Johnson & Finkel, 1992; Slack & Stewart, 1990; Stewart & Van Kirk, 1990). It was theorized that GenScope would help students turn information into knowledge by emphasizing this reverse pattern of thinking and by providing

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[1] The development of these programs is supported by the National Science Foundation. For details on the technological aspects, see Horwitz & Burke (2002).

students with opportunities to solve problems inductively and deductively (Christie, 1997; Horwitz, 1996).

The group of professional technologists involved in this work is focused on understanding optimal and effective uses of computers in education. From the beginning, we have gone into classrooms in an effort to understand the effectiveness of our work, specifically by offering technology-supported instructional materials to willing high school science teachers.

Early project research questions were exclusively product-focused. The first quasi-experimental research project was conducted at a local area urban high school, attempting to determine whether the use of technology increased science achievement in a "test" population relative to a "comparison" population.[2] Learning outcomes of the two populations (10th grade biology classes) were statistically analyzed for significant achievement differences. The treatment in the experimental design was the use of instructional technology as a replacement for the textbook in one class, whereas the comparison class used the textbook. The same teacher, in the same urban public high school, taught both classes, using the textbook in one and the computer in the other.

The differences in learning outcomes were not statistically significant, yet the behavioral differences I observed in the GenScope class were remarkable. Specifically, students in the treatment group performed poorly on the written exam, yet verbally demonstrated scientific understanding spontaneously, accurately, and much more deeply than students in the comparison group, who had performed just as poorly on the written test. Those students who had failed to demonstrate knowledge of genetics on paper-and-pencil tests were capable of demonstrating understandings *in situ*. Moreover, these students exhibited greater resilience and effort

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[2] Research hypothesis: Students who use the computer (*GenScope*) instead of a textbook will increase their levels of science learning.

(constructs I had not thought to examine in this study) and outperformed the control group on a small number of questions designed to assess critical thinking (Christie, 1997).

The students in the treatment group were exposed to a dramatically different kind of classroom where basic skills were not used as a hurdle to attempting complex reasoning and problem-solving tasks. Rather, they were confronted with increasingly difficult tasks and they faced these head-on with impressive, albeit mixed, results (Christie, 1997). This is consistent with widespread agreement among educators and psychologists (Collins, Brown, & Newman, 1989; Means, Chelemer & Knapp, 1991; Resnick, 1987) that advanced comprehension, reasoning, composition and experimentation skills are acquired through a learner's interaction with content rather than through transmission of facts.

Dr. Daniel Hickey, then at the Educational Testing Service (ETS), conducted a series of classroom-based experiments looking for a GenScope effect. As was consistent with the earlier reports, GenScope students did not statistically outperform the relevant comparison groups. However, with paper-and-pencil based scaffolding, one GenScope group in the Hickey experiments did outperform its control counterpart (Hickey, Kindfield, Horwitz & Christie, 1999).

It was at this point in the research history that the team first became divided with on the as regards the success of early efforts. The majority perspective is that the early work yielded failed experiments, citing insignificant differences between test and control groups as evidence of such failure. The minority perspective, which I myself hold, views the early research efforts as a success. These efforts yielded interesting, albeit paradoxical, data which I set out to follow, however unexpected.

Getting perspective

Curious about the different student performances across modalities, I began to ask students what they thought about their computer-based instructional experiences. I soon learned that GenScope students viewed these experiences not as a different way to learn, as the teacher and the researchers had, but as "somethin' more than learnin'" (Christie, 1999). GenScope students attributed themes to their learning experiences that echo educational literature in terms of reflection, incremental learning, and autonomy. Specifically, they described their computer-based experiences as follows: "We talked yet we were still learnin'," "It don't matter [that we didn't get it right], we *learned* somethin', that's what's *important*"; and finally, "We understood it more 'cause we were doin' it ourself." Moreover, these students spoke of learning in other classes in ways that resonate with traditional instructional methods: "They [teachers] just sit there and teach. And we just write ucchhh! It's aggravatin'! (sighs)," and "We don't go up there [to the blackboard]. She just tells us stuff."

The primary educational conclusion I drew from this first inquiry on students' computer-based experiences was one of a perceived cultural shift with respect to academic tasks. The gap between the learning opportunities available during the normal course of high school science instruction and hands-on, minds-on work that we made available through our intervention was so wide, that active science learning was a completely new experience for these students. One implication of this gap is that these students, and perhaps others like them, would need to "learn how to learn like a scientist" before they could learn to think like one. Learning to learn, a form of meta-cognition, is a particularly valuable skill for all students, but especially so for the student at risk. "The flexibility and competencies embedded in the techniques of learning *how* to learn may have the most lasting influences on student achievement" (Chipman & Segal, 1985, as referenced in Preissen, 1988, pg. 39)."

Analyzing the GenScope learning experience in student voice inspired me to construct the following grounded theory: instructional tasks themselves hold tacit theories of teaching and learning, and perhaps of academic success and failure as well. Moreover, different representations of a task designed to teach the same content could hold very different theories. According to this grounded hypothesis, for example, paper-and-pencil activities, where students traditionally must choose an answer, would put forth an "ability matters" model of teaching and learning. Conversely, hypermodel activities, where students would *construct* rather than *choose* potential answers, would put forth an "effort matters" model of teaching and learning. In the former model, ability would covary with success or learning, whereas in the latter model, effort would covary with success or learning.

This link between tacit models of teaching, learning, and instructional tasks is also present at an aggregate level of practice. For example, the ubiquitous aspects of science instruction I have observed in urban schools, such as direct lectures; vocabulary lessons; drill-and-practice routines; directed seatwork activities with end-of-chapter textbook exercises; and the "pop-quiz," would hold a theory of learning as entity-based–students either know the answer or they do not. Furthermore, these and other documented aspects of urban pedagogy (Haberman, 1991; Spencer, Dornbusch, Mont-Reynaud, 1990) would hold a tacit theory of teaching as "telling" and a tacit definition of academic success as the measured ability to memorize, recall, or otherwise apply procedural knowledge. Conversely, I argue that aspects of practice that emphasize problem-solving, experimentation, inquiry, and other hands-on or minds-on activities, which are more often found in suburban settings, hold quite different theories of teaching and learning, and quite different definitions of success and failure.[3]

Emerging perspectives

As previously discussed, our initial hypermodel research efforts with GenScope concerned such technology's ability to help students acquire cognitive schema of difficult science topics (Christie, 1997; Horwitz & Christie, 1999; 2000; Hickey et al. 1999).[4] The residual questions of these initial field experiences have necessitated a more discerning investigation of technology-supported learning and the influence of technology on these dimensions in educational and social contexts. In response, the theoretical framework has been broadened to include the multidimensionality of learning (cognitive, affective, behavioral, and social outcomes), the complex of research questions has been increased to include such constructs as school and classroom cultures, and the methodology has been expanded as appropriate.

Theoretical framework

The theoretical framework, which once consisted of science education theories and constructs alone, has been broadened to include the educational psychology of achievement. A long-standing discipline in educational and psychological research, the psychology of achievement has grown from the study of individual traits (e.g., the "need for achievement") to the study of the contexts in which achievement occurs (Lewin, 1957; Maehr & Midgley, 1996). Educational anthropologists (McDermott, 1997; Spindler, 1987), cultural psychologists (Bruner, 1996; Cole, 1998; Rogoff, 1998) and social psychologists (Brown, Bransford, Ferrara, &

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[3] In their recent book *The Connected School*, Means, Penuel & Padilla (2001) argue that these qualitative differences in urban and suburban pedagogies continue to reveal themselves in technology-supported practice.

[4] For details on BioLogica outcomes and the relevance to the study of classroom cultures, see Buckley, Gobert & Christie (2002).

Campione, 1983) have long suggested that human behavior needs to be understood in relation to context. Many of those who study the psychology of achievement have begun responding to this call.

Achievement motivation is the study of goal-directed behavior as it relates to educational settings (Weiner, 1990). Historically, links between students' perceptions, learning behaviors, and affective responses have received very little research attention (Schunk, 1992). However, in the last twenty-five years, there has been an increased interest in students' perceptions of their educational experiences. Moreover, motivation theory itself is experiencing a renewed vigor in educational psychology (Weiner, 1990), due in part to the importance of social cognition in educational settings and the study of meaning and context in research on learning (NRC, 2001).

The primary construct investigated by motivation researchers is *achievement cognitions*, which represent beliefs about related academic concepts such as intelligence, success (or failure), and the nature and purpose of learning (Ames, 1992; Dweck & Bempchat, 1983; Weiner, 1979). This research has consistently shown that achievement cognitions are strong predictors of adaptive learning behaviors and academic achievement–in some cases, stronger than individuals' prior achievement histories. Moreover, it has shown that learning is multidimensional, involving cognitive, behavioral, affective, and social outcomes (Weiner, Graham, Taylor, & Meyer, 1992). Although the current focus of this field is to examine aspects of classroom environments that contribute to adaptive beliefs and outcomes (Ames, 1992), until recently, achievement cognition research has never been conducted ethnographically or in educational contexts that are becoming increasingly technological (Christie, 2000).

In the first ethnographic study on the nature of achievement cognitions, I have found support for my long-standing theory that the details of instruction, including the representational modality of the task, influence students' achievement cognitions and related behaviors (Christie, 2001). In brief, the nature of instructional tasks was a salient theme by which students organized achievement cognitions. All students who regularly attended the 10th grade public high school biology class that I examined represented cognitions about success (failure) that were deeply entangled in the details of instruction. In this urban classroom, science was taught almost exclusively as facts, figures, and other information. Students' conceptualization of academic success experiences in science were all about the "answer" e.g., "success means knowin' the answer" and their academic strategies were completely aligned with those beliefs e.g., "show up," "pay attention," "take down the notes," and "study." When the teacher shifted to a constructivist, hands-on pedagogy through the use of the BioLogica hypermodel, several lower-achieving students differentiated their beliefs about success e.g., "In the computer room, I was learnin' because I was makin' mistakes." These students also constructed new academic strategies, which were, again, aligned with their beliefs about success.

The implication of this finding is exciting on two levels. First, it suggests that educators can influence academic achievement at its earliest inception – the point at which students' construct beliefs that influence their learning behaviors. Second, it suggests that technology has a role to play in achievement beliefs. I argue that to understand this role, we must first understand the contexts in which technologies are becoming integrated with instruction.

School and classroom cultures

"The real promise of technology in education lies in its potential to facilitate fundamental, qualitative changes in the nature of teaching and learning" (PCAST, 1997). Yet powerful technologies often get used in limited ways, which results in maintaining, rather than transforming instructional practice (Cuban, 2001). Limited use that leads to such maintenance is not necessarily due to limitations of technologies but rather to limitations of teachers' mental models of professional practice. Cultural psychologists and educational anthropologists refer to mental models of practice in relevant settings as "cultural knowledge" (Spindler, 1987).

The complexities of educational technology interventions arise on social and institutional levels, which include existing practice and relevant cultural knowledges. The effects of technology interventions will ultimately be known through understandings of the contexts in which they are embedded and the existing cultural knowledges that are constructed and applied there. In order to fully capture the influences that technologies have on education, we need to begin with the educational cultures and contexts in which we attempt to introduce change.

Consideration of context is therefore critical in educational technology research. However, context is more than the classroom environment, which in turn is more than the physical–even observable–characteristics of the room. I argue that context *becomes* culture through participants' construction and application of cultural knowledge. This view is consistent with Goldman-Segall's (1998) wish to look at school " ... not only as a place that disseminates culture to those who have no choice but partake in its rituals, but also as a place where cultures emerge and are created, layer upon layer" (p. 11).

This perspective on culture considers many layers, including prior and present teaching and learning experiences, past and present experiences with educational technologies, and the relevant beliefs and behaviors implicated in the examination of practice from the perspectives of teachers, students, researchers, and technologists. A sample of emerging research questions is provided below.

1. What are the school, science classroom, and instructional contexts in which we will later conduct longitudinal research?
2. What are teachers' and students' beliefs about teaching and learning of high school science?
3. What are teachers' and students' experiences in high school science classrooms?

4. What is the offering & availability of existing instructional technologies?
5. How often and in what ways are science teachers and students using computers in instruction?
6. What are teachers' and students' experiences of computer use in high school science?
7. What are teachers' & students' beliefs about and attitudes toward computer use in science teaching & learning?
8. What are teachers' beliefs about and experiences with change?
9. What are students' beliefs about and experiences with change?
10. Given the availability, use, experiences, & beliefs: in what ways have teaching & learning of high school science remained stable? In what ways have teaching & learning of high school science changed?
11. How can these data inform the instructional design of our technologies and related research efforts?
12. How can these culturally-specific notions shape a theory of effective institutional change?

Expanding Methodology

"We need far more analytical and empirical explanation for successes and failures [of learning technology experiences], particularly in K-12 and university education, with research methodologies that acknowledge the complexities of such interventions" (PITAC, 2001, p. 8). As reflected in this call for research, the effects of technology on education are not easily measured. This is particularly true of innovative technologies, which often challenge existing cultural models of teaching and learning by provoking thought about new possibilities. Some changes may be immediate and observable, such as a shift in teacher-centered to student-centered activities, whereas others may be tacit and incremental, as in new meanings or strategies that students' may construct concerning academic success.

Naturalistic evaluation and qualitative methods have emerged as approaches to study natural settings where innovations are introduced. This type of inquiry is fundamental to describe activities that take place in the setting, to understand the meaning of these activities for participants in that setting, and what is important about the innovation and the setting. Qualitative methodologies are therefore essential to understand the institutional, social and cultural complexities that are part of teaching and learning, both with and without technology. These inquiry methods serve to provide rich descriptions of existing practice and of the fundamental, qualitative changes that emerge with technology *in medias res*.

Phenomenological methods of inquiry do not preclude the use of quantitative measures. However in hypothesis-generating work, they certainly precede such measures. For instance, if constructivist technology is new to a given academic environment, it may be necessary to begin with qualitative methods to search out the how and why questions and to generate hypotheses about possible effects. In such an environment, quantitative data may be more appropriately collected after the use of the technology has stabilized and grounded hypotheses have been generated by naturalistic observation and inquiry in that particular context.

Finally, an important finding from a methodological perspective is the necessity to triangulate data (Bogdan & Biklen, 1982; Carini, 1975; Patton, 1990). With respect to the study of effects on human thought and behavior, particularly in educational settings, qualitative research methods must seriously be considered as a component in the design of all classroom-based research. The investigation of human phenomena as documented by descriptive, qualitative data, such as interviews or observations, may not fit a predictive model, as would quantitative test scores, but is far more valuable in capturing the human stories behind the research questions**.**

Closing Comments

The classroom serves not only as a place for student learning but also as a place where we ourselves, as technologists and researchers, become educated about student learning. The evolution of the hypermodel research efforts since 1995 is but one application of new understandings. There is much more to be learned. Teachers and students hold very strong -and likely very different-beliefs about the role of technology in teaching and learning. These beliefs, other cultural knowledges, and educational contexts will influence the ways in which technology is perceived, applied, and evaluated by teachers and students. Ultimately, the effects of the hypermodel (and indeed of any instructional technology) will depend on the culture and context in which it is embedded. I suggest that understandings of resultant educational effectiveness and technology's role therein will be most meaningfully developed one classroom at a time.

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