Leslie Moller
Jason Bond Huett
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Editors

Learning and Instructional Technologies for the 21st Century

Visions of the Future

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Preface

This volume of reading is the result of the first AECT Research Symposia. It represents some of the best thinking by leading scholars in our field. Before you begin to read the text, I would like to provide a bit of background that may help you, the reader, to better understand how this all came about and why the contributions in this text are important.

Starting in the summer of 2005 with the generous help of Phil Harris, Sharon Smaldino, Jim Klein, and Rob Foshay (among others), a plan was formulated to remedy common shortcomings that I felt were not being addressed at our typical conferences and gatherings. Specifically, at the large conferences, I observed scholars presenting their work while the audiences were often only passively involved and not engaging in any type of dialogue. While the reasons for this undoubtedly varied, the end result appeared to be a mode of discourse that actually discouraged real conversation from taking place. Yet, away from the sessions in more relaxed surroundings, fantastic conversations were happening.

Additionally, we have all heard the phrase that academics tend to be "an inch wide and a mile deep" – meaning that our academic training forces us to work in very small areas. Thus, we build new knowledge in isolated ways that is often disjointed or, at best, only tangentially connected to the work of our colleagues. These observations inspired those of us interested in the symposium to look for a new format to share information and ideas as well as foster dialogues and other relationships.

So, the idea for a research symposium was born. The organization was different from a typical conference. First, all presenters had to write on a singular topic, and papers had to be made available for sharing. Second, a deadline was established that allowed for sufficient time (prior to the symposium) for other participants to read and to consider each other's contributions. Third, all proposed sessions were longer than usually allowed at conferences, and the presenter only had a few minutes to "present" thus retaining the overwhelming majority of session time for intimate conversation among all the attendees.

Initially, the goal of the first symposium was to explore current research and new ideas in order to develop a response to *U.S. Department of Education's National Technology Plan*. The plan stated in part:

> To enable such important and sweeping changes to take place will require not only a rethinking and realignment of the industrial age factory model of education, but a rethinking of the tools available to support such change. Increased access to technology alone, however, will not fundamentally transform education.
>
> (http://www.ed.gov/index.jhtml)

While this is a noble goal, too often, in my experiences as an academic and a practitioner, I encounter the thinking that more or better technology is the solution to improving education and reform seems to stop there. There is no denying the importance of technology. However, many might argue that technology's main advantages lie in its ability to enable advanced learning designs and emerging paradigms as well as to evolve learning interactions. In short, without sufficient consideration to the *process* of learning and all that it involves, technology, by itself, is not going to make a real difference. If we accept the words of Secretary of Education Dr. Rod Paige, quoted here from his introduction to the 2004 *Visions 2020* report, (and also included in the DOE plan) that

> ... schools remain unchanged for the most part despite numerous reforms and increased investments in computers and networks. The way we organize schools and provide instruction is essentially the same as it was when our Founding Fathers went to school. Put another way, we still educate our students based on an agricultural timetable, in an industrial setting, but tell students they live in a digital age (US Department of Commerce, 2002)

In light of Dr. Paige's remarks the magnitude of what we are trying to accomplish becomes clear. We should not just be adding more or better technology to an existing system; we should be *starting over and creating an entirely new system*. The seeds of an educational Renaissance are finally being planted. In that vein, the first symposium's goal was to answer the DOE's call by identifying specific research-based learning and instructional technology ideas which could rethink learning, reorganize schools, redirect technology, and provide new forms of instruction as well as a vision for the future.

One of our initial hopes was to condense all these ideas into one specific response to the perceived weaknesses (particularly regarding instructional design and the learning sciences) found in the DOE's *National Technology Plan*. Our desire was to create a "white paper" that AECT would consider as a public statement or policy.

Unfortunately, even though the symposium was a tremendous success, breaking new ground in the way it was conducted, reaching impressive levels of participant interaction, and resulting in the outstanding papers contained in this volume, we failed to develop a consensus or formal white paper. As the organizer, I take full responsibility for this. In hindsight, it becomes apparent that I should have given greater attention to the consensus building aspect of the symposium. However, within these covers, you will find great essays and innovative ideas that begin to tackle the challenge laid-out by the DOE. This book presents the "best of the best" in the fields of technology and learning. To help breathe new energy into the concepts presented here, we asked Marcy

Driscoll and Rob Foshay to each add a chapter where they reflect on the thoughts and ideas contained in this volume. Marcy and Rob's contributions are not typical; they were given the freedom to reflect, to improvise, and to free-think about what they had read. Their important contributions invite the reader to reexamine what he or she learned in the previous chapters.

As this book goes to the publisher, the second symposium is taking place. It is my deepest hope that AECT will continue to host this biannual event and that we will continue to improve upon its effectiveness and spirit of collaboration. I firmly believe improving education requires a collaborative effort. We cannot move forward like the proverbial three blind men trying to describe an elephant: each of us fixated only on our tiny piece. After all, how can we reach an understanding of the whole if we never investigate the total of the parts?

Transforming education is no small task, but it is a necessary one. As you read through the pages of this book, it might serve to remember The Roman Rule: "The one who says it cannot be done should never interrupt the one who is doing it."

In closing, I want to thank some individuals and groups of people who made this book possible. First, I am very grateful to Jason Huett and Douglas Harvey for helping to edit and to organize this book. Without their significant work and help, you would not be reading this.

Elizabeth Boling and the faculty, staff, and students of the University of Indiana deserve acknowledgement and praise for welcoming the symposium to their campus and for their help running the numerous day-to-day activities that go on behind the scene.

I would like to make a special point of acknowledging the contributions of Tom Duffy and David Jonassen. Tom and David served as inspirations, motivators, and problem solvers in the best traditions of academia. The symposia and the resulting book would not have happened without their guidance and attention.

I hope you enjoy the book!

Peace,

Vermillion, South Dakota Leslie Moller

Contents

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Adventures and Advances in Instructional Design Theory and Practice

J. Michael Spector

Abstract Learning is fundamentally about change – persistent change in a person's abilities, attitudes, beliefs, knowledge, mental models, and skills. In the past, technology to support learning has been touted as offering many opportunities for dramatic improvements in learning. Unfortunately, many of these so-called advanced learning technologies have not resulted in substantial and sustained improvements in learning. Critical to progress in improving learning is measuring a person's abilities, attitudes, beliefs, knowledge and so on before, during, after, and long after instruction. Such assessments are rarely made in a way that can demonstrate that learning has occurred. These assessments are even more challenging when the domain of interest involves complex and ill-structured problems. In this chapter, some progress in assessing learning in complex problem domains will be described.

Keywords Instructional design theory · Instructional technology · Learning · Cognitive psychology · Motivation · Cognitive load · Complex domains · Systems-based approaches · Technology integration · DEEP methodology

Introduction

There have been many transformations over the years in the practice of planning and implementing instruction.[1] Some of these changes were due to the introduction of a new technology, such as mass-produced books. Some transformations were due to changes in where and how people work. For example,

[1] This chapter is based on the keynote address delivered by Prof. Spector at EARLI-ID in June, 2006 in Leuven, Belgium. These remarks also formed the basis for the shared session between the EARLI meeting and the AECT Summer Research Workshop.

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learning on the job was a common practice confined for many centuries to craftsmen; the industrial revolution brought about the need to train specific skills for many workers in the workplace setting. More recently, advances in cognitive psychology and new digital technologies have brought about many changes in both the theory and practice of learning and instruction.

Nonetheless, no single theory of learning explains the many ways people learn or fail to learn. Likewise, no single model of instructional design seems to apply to a vast majority of learning situations. There are surprisingly few empirically established principles to guide the design of effective instruction, and the few that are widely accepted lack sufficient granularity to inform instructional design practice.

While these claims can be and are challenged by some researchers and practitioners, the discussion will proceed as if they are not controversial. We know less about learning and the design of effective instruction than we might be inclined to believe. Basic learning principles and promising technologies that seem to have implications for instructional design practice will be reviewed. A key issue in determining the efficacy of proposed applications of learning principles to design practice will be examined – namely, how to determine progress of learning in complex domains and associate changes in learning and performance with specific aspects of instructional interventions. A promising approach to this central challenge that makes use of dynamic problem conceptualizations will be presented, and problematic aspects of this approach will be examined and discussed.

In the Preface to *Impact of Research on Education: Some Case Studies*, Patrick Suppes (1978) said "all of us on occasion probably feel that there is little hope that research, given the small national effort devoted to it, will seriously affect practice" (p. xiii). In spite of much research on learning and instruction, there is still much that we do not understand and much more that could be done to improve learning and instruction based on what we do understand. Meanwhile, cognitive psychology moves on and technologies that are used to support learning and instruction change. In 1972, in his keynote address to the Association of Computing Machinery, Edgars Dijkstra said "the electronic industry has not solved a single problem; it has only created them; it has created the problem of using its products" (p. 861).

In spite of sustained enthusiasm about information and communication technologies, there is the fact that these technologies change frequently. Moreover, implementing a new technology introduces the problem of learning to use that technology effectively – this is particularly a challenge in educational contexts (Spector, 2000). The changing nature of technology and the associated challenges for learning and instruction are too numerous to mention. However, the fact that an important educational resource, the Education Resources Information Center (ERIC) Clearinghouse on Information and Technology, was closed, along with all 16 ERIC clearinghouses and 10 adjunct clearinghouses, represents the impact of changes in technology. These clearinghouses had been serving various educational constituencies since 1966; they had attracted large groups of users all over the world, including researchers, teachers, students, librarians, media specialists, technology coordinators, and administrators. ERIC continues but without those clearinghouses. Perhaps ERIC service and support is as good as it had been – many do not think so since so much less is now available. Regardless, those who were used to the resources made available through those clearinghouses have had to adjust what they do. Technology changes.

Technology changes what people do. More importantly, technology changes what people *can* do. People can teach and learn with technology (see, for example, Jonassen, 2006; Lowyck & Elen, 2004; Spector & Anderson, 2000). New technologies provide new opportunities to improve learning and instruction. However, in spite of significant investments in research and technology, education has not changed all that much. The promised dramatic improvements in learning have not been realized. If one judges educational improvements by their impact on society, then one can see what led to the negative view about educational research to which Suppes (1978) referred.

I am reminded of the opening words in a well-known Biblical text which can be loosely translated as follows: *In the beginning there were chaos and confusion*. Before modern research on learning and instruction, there were, perhaps, chaotic and confused approaches to teaching, with various teachers using different strategies and resources, aiming to achieve quite different things. One might conclude that not much has changed since that inauspicious beginning. What have ensued might be called *adventures* although some would like to claim them as *advances*. I am not convinced. An adventure is an exploration of new territory. I think this – the notion of an adventure – most appropriately describes where we are with regard to instructional design practice and the foundations of learning theory and the psychology and sociology of development on which it rests. An advance represents a significant contribution to knowledge which has wide applicability and predictable outcomes. In my view, we have seen far too few advances in learning theory and instructional design practice.

Research on Learning and Instruction

What has been established by learning research in the last 50 years or so? Cognitive psychology has established much about memory and its role in learning. There are limitations to what individuals can hold in short-term memory that do not seem to vary significantly with age, gender, experience, or other individual differences (Miller, 1956). The cognitive architecture developed by Anderson and colleagues (2004) is widely accepted and based on multiple types of representations in memory – textual and visual, primarily. Paivio (1986) and others argue that multiple perceptual cues can facilitate storing and retrieving specific items from memory. Cognitive psychologists have contributed much more in terms of our understanding about learning, than these few items (see, for example, Kintsch, 1993; Polson, 1993).

Learning is fundamentally about change. When we say of any organism that it has learned, it is clear that there is an implication that the organism has changed in some observable way. With regard to that rather peculiar organism *Homo sapiens*, relevant changes may involve abilities, attitudes, behaviors, beliefs, mental models, skills, or any combination of these. This definition of learning focuses on the dialogical implications of claiming that learning has occurred and not on the various cognitive or social processes that might be involved in fostering those changes. It is certainly true that those processes are important, as are efforts to get people to believe they can learn, to become motivated to learn, to engage in learning activities, and to monitor their own progress of learning. However, the focus in this discussion is on the claim that a stable and persisting change has occurred.

Typically, observing changes, and thereby establishing that learning has [or has not] occurred, involves identifying relevant response patterns involving abilities, attitudes, behaviors, beliefs, and so on. Many things make it difficult to determine that learning has occurred or why learning did or did not occur as expected. First and foremost, there is the fact that humans are naturally engaged in learning most of the time. Much of what we learn occurs incidentally or accidentally or unintentionally. In order to conduct research on learning, instructional design researchers typically focus on intentional learning that occurs in somewhat structured settings (such as schools) in which there is a goal or aim or objective that can be identified and clarified or negotiated and against which progress of learning can be assessed. This kind of applied educational research is quite different from the more basic research, the research conducted by learning psychologists in laboratory settings in which small problems are presented to subjects in easily controlled circumstances.

Cognitive researchers readily admit that many non-cognitive aspects influence learning, including such affective factors as motivation and prejudice. Motivation plays an especially significant role in the development of expertise (Ericsson, 2001). Social and incidental interactions with others affect how well one learns and performs (Moreno, Mayer, Spires, & Lester, 2001; Salas & Fiore, 2004).

Many of the findings pertaining to research on learning are summarized in Bransford, Brown and Cocking (2000). Among these findings are these:

- Students have preconceptions about how things work, and these preconceptions (often misconceptions) need to be taken into account in learning activities.
- The development of competence requires foundational knowledge, a conceptual framework, and the ability to organize and retrieve knowledge.
- Metacognitive approaches can facilitate learning and improve performance.

These findings are consistent with and reinforced by model-facilitated learning (Milrad, Spector, & Davidsen, 2003), cognitive apprentice (Collins, Brown, & Newman, 1989), model-centered learning (Seel, 2003), and other such instructional design approaches.

Lowyck and colleagues (Lowyck & Elen, 2004; Lowyck, Pöysä, & van Merriënboer, 2003) also provide a compact and meaningful summary of the findings of learning research that have implications for instructional design and the effective use of technology. Their findings pertaining to goal-directed learning include these:

- Learning is an active process that typically involves mental effort.
- Learners interpret their experiences and construct internal representations.
- Learning is cumulative; new knowledge is most useful when it is integrated with prior knowledge.
- Effective learning is self-regulated.
- Learning occurs in contexts that include both physical and socio-cultural aspects.

The mental effort that is associated with intentional learning has been explored by cognitive load researchers (Paas, Renkl, & Sweller, 2003; Sweller, 2003), who distinguish intrinsic cognitive load (largely due to factors in the problem itself), extraneous cognitive load (largely due to incidental aspects in the presentation of the problem or in the environment in which it is presented), and germane cognitive load (generally beneficial to learning and dependent on individual characteristics and circumstances). It is important to note that what is relevant with regard to each type of cognitive load is not an objective determination of the load, but the perceived load to individual learners. It should be obvious that a highly experienced person in a particular domain may find the intrinsic or extraneous load in a problem that is presented to be quite low, whereas a much less experienced person presented with the same problem might find the intrinsic or extraneous load to be quite high. Factors in the problem situation pertinent to support learning (germane load) will very likely differ for persons with different levels of experience and prior knowledge.

Merrill (2002) developed a set of first principles for the design of instruction based on an examination of the leading success stories in educational research and instructional technology: Star legacy (Schwartz, Lin, Brophy, & Bransford, 1999), McCarthy's (1996) 4-Mat, Andre's (1986) instructional episodes, Gardner's (1999) multiple intelligences, Nelson's (1999) collaborative problem solving, Jonassen's (1999) constructivist approaches (1999), and Schank, Berman, & McPherson's (1999) learning by doing. These approaches and their associated learning systems, along with those mentioned earlier and others too numerous to mention, represent the great adventures in instructional design research and technology. Merrill's (2002) principles include adopting a problem-centered instructional approach, activating relevant knowledge structures and expectations in learners, demonstrating how to solve problems, providing problem-solving practice and opportunities for applying knowledge, and integrating what has been learned into meaningful activities.

Spector (2001) provided a synthesis of this general body of educational research in the form of the following naturalistic educational epistemology:

- Learning is fundamentally about change – change in attitudes, behavior, beliefs, capabilities, mental models, skills, or a combination of these.
- Experience is the starting point for learning and improved understanding – indeed, experience is woven tightly into and throughout a learning process in the form of observations, recollections, hypotheses, reflections, thought experiments, actual experiments, and much more.
- Context determines meaning as interpreted and constructed by individuals – this represents a broad application of a pragmatic approach to semantics.
- Relevant contexts are often broad and multi-faceted; effective learning integrates multiple aspects of new contexts with existing knowledge and understanding.
- Effective learning begins from a position of humility and uncertainty – that is to say, with an admission (explicit or tacit) of not knowing or understanding.

These various summaries indicate a high degree of agreement among educational researchers about the implications of research on learning for the design of instruction. Why, then, is there so little application of these findings beyond the involved research groups to improve learning and instruction systemically? Moreover, why have we not seen systematic benefits accrue to society from improved learning and instruction? Perhaps educational practice is not as evidence based as one would like to imagine. Alternatively, perhaps there have been large-scale improvements that this author is overlooking. In what follows, the former is assumed to be the case and an assessment methodology intended to improve evidence-based instructional design research is presented.

Assessing Learning in Complex Domains

I believe the apparent lack of progress in reaping the benefits of research on learning and instruction is a result of a failure to deal effectively with learning and instruction as educational systems.[2] It is the inability to conceptualize education as involving complex and dynamic systems that inhibits progress. In this section, I provide an overview of research related to learning in and about complex systems and focus in particular on an assessment methodology that is pertinent to evidence-based decision making in learning and instruction.

A system can be roughly defined as a collection of related components with inputs and outputs. Representations of systems typically restrict the boundaries of what will be considered as an integral part of the system. Decisions about

[2] The work reported in this section began at the University of Bergen and was continued at Syracuse University as part of a National Science Foundation Project entitled “The DEEP Methodology for Assessing Learning in Complex Domains” (Spector & Koszalka, 2004).

what is integral to a system are often arbitrary. With regard to educational systems, for example, one might decide that certain aspects of home life (e.g., the presence of two parents, parental reading at home, etc.) and extracurricular activities (e.g., participation in school clubs and sports) form an integral part of the system, whereas other aspects of home life (e.g., diet) and extracurricular activities (e.g., dating) are not represented as integral aspects. This discussion is not about what properly constitutes an educational system. Rather, the focus is on the notion of an educational system, and particularly on instructional and learning systems within an educational system.

Systems-based approaches to learning and instruction have been around for more than 50 years and have recently been integrated into assessment and evaluation (Seel, 2003; Spector, 2004). Findings from systems-oriented research on learning and instruction in complex, ill-structured problem domains suggest that learners often fail to comprehend the nature of a system – how various factors are interrelated and how a change in one part of the system can dramatically affect another part of the system (Dörner, 1996; Spector & Anderson, 2000). A number of instructional approaches already mentioned address this deficiency directly, including problem-centered learning (Merrill, 2002) and variations such as model-centered learning (Seel, 2003) and model-facilitated learning (Milrad et al., 2003).

A common theme in systems-based approaches is the notion that the full complexity of a problem situation should eventually be presented to the learner, and that helping the learner manage that complexity by gradually introducing additional problem factors can contribute to effective learning. Challenging problems typically involve a complex system, and instruction should be aimed not only at a specific facet of the problem but also at the larger system so as to help learners locate problems in their naturally larger contexts; this has been called a holistic approach (Spector & Anderson, 2000) or a whole-task approach (van Merriënboer, 1997). Methods to facilitate understanding in such complex contexts include presenting multiple representations of problem situations (Spiro, Feltovich, Jacobson, & Coulson, 1991), interactions with simulations of complex systems (Milrad et al., 2003), and partially worked examples (van Merriënboer, 1997). Learner-constructed problem representations of the type to be described below have implications for instruction as well as for assessment.

The integration of technology in teaching and learning can be closely linked to systems-based approaches making use of such technologies as powerful and affordable computers, broadband networks, wireless technologies, more powerful and accessible software systems, distributed learning environments, and so on. Educational technologies provide many valuable affordances for problem-centered instructional approaches. The learning technology paradigm has appropriately shifted from structured learning from computers to one better characterized as learning linked with instructional uses of technology, or learning with computers (Lowyck & Elen, 2004). The emphasis is on (a) viewing technology as an ongoing part of change and innovation and

(b) using technology to support higher-order learning in more complex and less well-defined domains (Jonassen, 2006; Spector & Anderson, 2000). The latter is a concern for many educational researchers (see, for example, Project Zero at Harvard University; http://pzweb.harvard.edu/).

Learning environments and instructional systems are properly viewed as parts of larger systems rather than as isolated places where learning might occur. Moreover, learning takes place in more dynamic ways than was true in the teacher-led paradigm of earlier generations. Many more learning activities are made possible by technology and this further complicates instructional design – that is to say, determining how, when, which, and why particular learning activities promote improved understanding. Lessons learned in previous generations of educational technology should be taken into account. For example, simply putting sophisticated technologies into a learning environment is not likely to be either efficient or effective. Previous studies have focused on the effects of a particular technology on attitudes, motivation, and simple knowledge tests. Such studies perpetuate a wrongheaded debate about the educational efficacy of media (Clark, 1994; Kozma, 1994). What should be studied is the impact on learning in terms of improvements in student inquiry processes and other higher-order aspects of learning, directly relevant to understanding challenging and complex subject matter (Lowyck et al., 2003; Spector & Anderson, 2000).

To demonstrate that specific instructional approaches and educational technologies are effective in improving complex problem-solving skills, a methodology to determine higher-order learning outcomes appropriate for such problems is required. A pilot test of such a methodology was demonstrated and discussed at the 2000 International System Dynamics Conference in Bergen, Norway (Christensen, Spector, Sioutine, & McCormack, 2000). A similar methodology developed in Germany has shown promise (Seel, Al-Diban, & Blumschein, 2000). General findings of a 1-year National Science Foundation (NSF) study involving this modeling assessment methodology are discussed next.

The NSF project entitled "The DEEP Methodology for Assessing Learning in Complex Domains" (see Spector & Koszalka, 2004 for detailed findings; only high-level summaries are reported here) examined the use of annotated problem representations to determine relative levels of expertise in biology, engineering, and medicine. Complementary studies with similar results have been reported in the literature (Seel et al., 2000; Stoyanova & Kommers, 2002; Taricani & Clariana, 2006). The DEEP study involved the selection of two representative problem scenarios for each of three complex problem-solving domains (biology, engineering, and medicine). Subjects included both expert and non-expert respondents; they were provided with a problem scenario and asked to indicate what they thought would be relevant to a solution. Subjects were asked to document these items, providing a short description of each item along with a brief explanation of how and why it was relevant. Subjects were asked to indicate and document assumptions about the problem situation that they were making (initially and again at the end of the activity). Subjects were asked to develop the representation of a solution approach – but not a solution. Required parts of this representation included (a) key facts and factors influencing the problem situation; (b) documentation of each factor – for example, how it influences the problem; (c) a graphical representation of the problem situation that linked key factors (see http://deep.lsi.fsu.edu/DMVS/jsp/index.htm for online access to the DEEP tool); (d) annotations on the graphical representation (descriptions of each link and each factor); (e) a solution approach based on the representation already provided, including additional information that would be required to fully specify a solution; and (f) an indication of other possible solution approaches (very few of the respondents provided this last item).

Findings suggest that the DEEP method can be used to predict performance and relative levels of expertise in some cases (Spector & Koszalka, 2004; Spector, Dennen, & Koszalka, 2005). Expert representations were noticeably different from those of non-experts, although there were also differences among expert responses. There was much variation in non-expert responses. Differences occurred at three levels of analysis (surface, structure, semantic). In general, experts tended to identify more relationships among factors and generally said more about factors and links. In most cases, experts tended to identify more causal relationships as opposed to other types of relationships, although this was not the case with expert medical diagnosticians. As it happens, expert medical diagnosticians are very familiar with standard diagnostic procedures and used that knowledge to quickly develop a representation reflecting the standard diagnostic procedure; non-experts (medical school interns in this case) had extensive knowledge of the human body from recent coursework, and they used that knowledge to reason through a sequence likely to be result in a successful diagnosis. In other words, expert diagnosticians made use of a schema when reacting to the problem situation, whereas non-expert diagnosticians had to construct a causal mental representation of the problem. In the other domains, experts tended to reason more in terms of causal relationships than did novices. This variation across problem domains indicates that the DEEP methodology is sensitive to and useful in identifying such differences.

In all three problem domains, experts and non-experts exhibited noticeable differences in identifying key or critical nodes identified. Experts identified similar critical nodes (the most inter-connected nodes), whereas the critical nodes identified by non-experts differed significantly from those experts and also from each other. For example, in response to one of the medical scenarios, none of the experts cited *stress* as a critical factor yet some non-experts did. Expert medical diagnosis was driven by evidence based on tests as the most critical factor; experts also mentioned follow-up visits and tests, while non-experts did not mention these things. In short, differences in the responses of experts and non-experts were evident at the surface and structural level (critical nodes) and also at the semantic level (what they said about specific nodes).

In the DEEP study, there was no opportunity to examine changes in problem representations over time or through a sequence of instructional sequence or period of sustained practice. The goals were to determine (a) if the annotated problem representation methodology was suitable for use in multiple domains, (b) if it would show differences in expert and non-expert responses, and (c) whether or not it could provide a basis for assessing relative level of expertise. These goals were achieved. The next steps are to investigate the utility of DEEP in assessing changes in how individuals and groups represent problems and to integrate the method into a personalized feedback for problem-solving activities (Spector et al., 2005). This implies using the method with both individuals and small groups before, during, and after instructional sequences and periods of deliberate practice. It is our hope that the DEEP method can be used to assess team problem solving and predict team performance on complex cognitive tasks as this is a much under-explored area of research with significant societal implications. DEEP has the potential to become the basis for personalized and high-level feedback to individuals and groups, and may improve the development of metacognitive skills and self-regulation.

The DEEP methodology has the potential to scale up for use in educational and performance settings involving many individuals, whereas the more traditional think-aloud protocol analysis methodology is suitable only for examining a small number of individuals in order to investigate particular hypotheses with regard to learning and performance. The DEEP methodology has the additional advantage of being easy to learn and implement, which makes it potentially suitable for classroom and workplace use. Further refinements of the methodology and the associated tool, including extensions for use with small groups and problem-solving teams, are required. Moreover, investigations of more problems in more domains with persons at different levels of knowledge and skill are required in order to develop more precise and reliable assessment metrics. Finally, the DEEP tool is useful in revealing differences in types of problems and how they are perceived by different problem solvers. Such knowledge is relevant to understanding the development of problem-solving skills in individuals and teams.

Variations and precursors of this methodology have been effectively demonstrated in other domains (see, for example, Dummer & Ifenthaler, 2005; Herl et al., 1999; Novak, 1998; Schvaneveldt, 1990). In addition to measures associated with DEEP and other assessment tools, it is possible to collect relatively reliable data, such as quantitative measures of measures of similarity to expert responses (e.g., presence/absence of salient features and their location in a concept map). By themselves, these do not provide insight into the progressive development of expertise or improvement in higher-order reasoning, especially in complex, ill-structured problem-solving domains, but they may predict performance on many types of complex problems. It is also possible to collect and analyze qualitative data, including responses to problem scenarios and think-aloud protocols. However, these are time-intensive and costly and, as a consequence, they are hardly ever used when a laboratory effort scales up to full-scale implementation; such qualitative measures are simply not useful for assessing large numbers of individuals or evaluating programs. The promise of DEEP (Spector & Koszalka, 2004) and other automated tools (Dummer &

Ifenthaler, 2005) is that changes in individuals and teams can be assessed in real time and through a sequence of instruction or period of practice.

In DEEP, the learner or group is asked to construct an annotated problem representation to determine how that learner or learning group is thinking about a particular problem situation. Once the learner or group constructs the diagram, it can be compared with the one created by an expert practitioner and immediate feedback provided to the learner that is specific to that learner's representation. As these problem scenarios are accumulated, it is possible to determine if learner responses increasingly reflect expert-like conceptualizations (factors, complexity of interactions among factors, and explanations of relationships). In sum, it is possible to use the DEEP methodology to predict how problem representations will develop and change in individuals and groups. This is consistent with other researchers who have studied the progressive development of mental models (Dummer & Ifenthaler, 2005; Ifenthaler, 2007; Ifenthaler & Seel, 2005; Ifenthaler, Pirnay-Dummer, & Seel, 2007; Pirnay-Dummer, 2007; Seel, 2003).

The DEEP tool has recently been integrated with the tools developed by Dummer and Ifenthaler (2005) into HIMATT – Highly Interactive Model-based Assessment Tools and Technology. The second tool in HIMATT allows a person to respond to a problem situation verbally or by entering text when asked about the key factors and their relationships (Pirnay-Dummer, 2007). An association network is then automatically generated. The third tool in HIMATT supports the analysis of two concept maps or problem conceptualizations using different dimensions of analysis that include a surface analysis (e.g., the number of nodes and links, the shortest and longest path across the network, etc.), a matching analysis (e.g., the identification of the same or similar nodes), and a deeper analysis (e.g., the identification of similar structures and semantics); the analysis produces similarity metrics that range from zero (no similarity) to one (identical graphs) (Ifenthaler, 2007).

To Go Where None Have Gone

The goal of instruction is to facilitate learning – to help people. The goal of learning, especially learning that is associated with schools, colleges, and formal training, is to help people by helping them to improve performance and understanding. The goal of improving performance and understanding is to enjoy better lives in some way. As Suppes (1978) noted, there has been some concern that the links in this chain have not been well connected. Indeed, one could conclude that things have not changed much since 1978 nor from that beginning in which there was so much chaos and confusion. We have wandered about in the wilderness of new technologies and paradigms for learning and instruction for more than a generation. We have had some interesting and wonderful adventures. However, the real work of systematically and systemically improving learning and instruction – of learning to use technology effectively to improve learning and instruction – has only just begun. Perhaps our students will be able to go where we and others have failed to go – into the hearts and minds of people who need to learn to share limited resources, tolerate different perspectives, and become better neighbors. Perhaps our students will turn our bold adventures into sustainable advances.

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Coming at Design from a Different Angle: Functional Design

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Abstract This chapter defines a non-traditional view of the structure of instructional designs that holds implications for the practice of instructional designing: what we call a theory of design layering. We discuss designing in many fields as a backdrop against which we examine this theoretical view of instructional design. We describe our design approach briefly as a set of propositions. Finally we examine the implications of the design layering approach for everyday design practice and the relation of instructional theories to instructional design.

Keywords Communication · Design layering · Design metaphors · Functional design · Instructional design theory · Instructional technology

What happens at the moment of design is a tantalizing mystery. Philosophers (Polanyi, 1958) and pragmatists (Jones, 1992) have puzzled over it, circling at the edges of the question but finding it hard to reach the heart. Conceptions of design found in the literature of many fields call up the figure of the blind gurus and the elephant ("it is very like a rope," "it is very like a tree"). This chapter defines a non-traditional view of the structure of instructional designs – a different way of looking at the elephant – that holds implications for the practice of instructional designing. As we have expressed elsewhere (Gibbons & Rogers, Submitted):

> ...This architecture of instructional theory accomplishes the following: it gives designers a tool to create quality designs more consistently, it can facilitate communications about designs and theories, it can allow designers to work efficiently in design teams with a greater degree of mutual understanding, it suggests functionalities for more advanced and productive design tools, and it allows experienced designers to convey design knowledge and judgment to novices more quickly.

In this chapter, we will concentrate on the implications of this view of instructional designing – what we consider to be a layered design theory – for

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everyday instructional design practice. First we will discuss designing in many fields as a backdrop against which we can examine our particular view of instructional design. This will provide a context to show where our ideas originate. Then we will describe our design approach briefly in the form of a set of propositions. Finally we will examine some of the implications of this approach for everyday design practice.

Design Metaphors from Many Fields

Design theorists take their perspective from the design problems they encounter most often, from traditions in their fields, and from design priorities they consider most important. Lacking direct answers, they often invoke metaphors:

- Design is a *reflective conversation* with the problem (Schön, 1987). This includes reflecting after each move to determine what you have learned from it. There is no particular order in designing, but one decision can be taken as an anchor ("imposing a discipline"), following which the designer plays out its implications. Decisions can be undone ("breaking the discipline") and a new anchor chosen as a beginning point for playing out new "what-ifs."
- Design as the progressive *placement of constraints*. This view stipulates that designing involves exploring regions of feasible solutions; that feasibility is derived from the constraints chosen by the designer; that choosing constraints is how a designer uses his knowledge. Every exercise of design knowledge is construable as the choice of a constraint on the space of possible inventions. The purpose is to make explicit design knowing and reasoning: "the accumulation of constraints becomes the invention" (Gross, Ervin, Anderson, & Fleisher, 1987). In this view, the designer can also deliberately select constraints as boundaries within which creative solutions will be sought, narrowing the focus to designs only within those bounds. Stokes (2006) proposes this as the method used by many art and design masters to stimulate breakthroughs that lead to new schools of design thinking.
- Design as *search*. Simon (1999) describes design as a search in which missing means-end relations are sought. Design consists in part of looking for the contents of a black box whose inputs and outputs are known but whose contents can take many forms. Tsourikov (Garfinkel, online) has embodied this approach in "invention machine" software that searches a large pool of means-end mechanisms in terms of inputs and outputs required by a specific problem to return all known mechanisms that can potentially be made to fill the box.
- Design as the *application or assembly of patterns* (Alexander, 1979). Alexander describes architectural design in terms of the assembly of elements from an abstract pattern language. Designs using these languages contain structures

matched to the activities of those who will use them and bring a "living" quality to the design. Polanyi (1958) describes the existence of "operational principles" that embody the abstract mechanism of a technological artifact.

- Design as a *social process* that involves defining common terms, forming goals, and reaching consensus (Bucciarelli, 1994). "Shared vision is the key phrase: The design is the shared vision, and the shared vision is the design – a (temporary) synthesis of the different participants' work within object worlds. Some of this shared vision is made explicit in documents, texts, and artifacts – in formal assembly and detail drawings, operation and service manuals, contractual disclaimers, production schedules, marketing copy, test plans, parts lists, procurement orders, mock-ups, and prototypes. But in the process of designing, the shared vision is less artifactual; each participant in the process has a personal collection of sketches, flowcharts, cost estimates, spreadsheets, models, and above all stories – stories to tell about their particular vision of the object. . . . The process is necessarily social and requires the participants to negotiate their differences and construct meaning through direct, and preferably face-to-face exchange." (p. 159).
- Design as *engineering*. Vincenti (1990) describes an engineering process that requires the application of several categories of technological knowledge, including abstract concepts, material and mechanism behavior data, and practical designing know-how. To the degree the designer possesses all of these kinds of knowledge at some level, designs become possible. Design can be pursued as a method for creating new shared, public knowledge as well as being a routine pursuit for the creation of new designs.
- Design as *prototyping and iteration*. Schrage (1999) describes the progressive invention of products and systems through constant iteration in modeling and testing. Problems become understood in the process of modeling, and fit with context becomes understood through rapid cycles of testing and revision. The spreadsheet is one of the most powerful computer tools for modeling business solutions because multiple scenarios can be generated and tested in principle in extremely short cycle times. Scenario generation encourages the designer to explore the principles that generate solutions in order to avoid random brute combinatorics.
- Design as *tinkering* with the application of *problem solving methods*. Through knowledge of a wide spectrum of design techniques, designers can advance toward solution, changing techniques as the needs of the solving process change with the stage of solution (Jones, 1992).
- Design as the *application of process or category system*. Design can be made accessible to a larger audience of designers by formulating sound principles into process descriptions (Branson & Grow, 1987) or by simplifying understanding of complex phenomena using taxonomic category systems (Gagné, 1985).

Each of these metaphors affords the designer a window into the heart of designing, but none of them captures the entire experience of designing.

The dominant metaphor of instructional design for the largest number of designers for nearly 40 years has been the application of processes and category systems. However, recently the search for alternative approaches has intensified.

Functional Design

Our design theory is expressed as a set of propositions below. A full treatment of this approach to design and its relation to an architecture of instructional and instructional design theories is given in Gibbons and Rogers (Gibbons & Rogers, Submitted).

1. *Design problem solving involves the decomposition of a design problem into sub-problems of solvable size*. A major part of designing involves clarification of the design problem itself. Once the problem is identified, or as intermediate steps toward the problem are identified, the task of designing becomes to decompose the complete problem into sub-problems of solvable size. This principle is expressed in the work of Simon (1999), Schön (1987), Alexander (1979), and others in diverse design fields and is implicit in virtually all current instructional design models.
2. *It is possible to consider a principle of problem decomposition that decomposes the design problem in terms of the functions to be carried out by the type of artifact being designed.* Schön (1987) describes architectural designs in terms of sub-problem "domains" that represent major functional divisions of the entire design problem. Gibbons (2003) describes a set of functional problems that are solved in the design of the general case of instructional design problems:

   - Content – The designer may specify the nature of the elements used as divisions of the subject-matter. Numerous theories of content structure can be found in theories of instructional design, including the content divisions of cognitive apprenticeship (Collins, Brown, & Newman, 1989), the objectives' taxonomies of Gagné (1985) and Merrill (Merrill & Twitchell, 1994), the description of semantic nets (Carbonell, 1970), and the knowledge structure theory of John R. Anderson (1993). Jonassen, Tessmer, and Hannum (1999) and Gibbons (1977) identified and classified numerous pre-design analysis methodologies. Each methodology can be seen as an expression of a theory about the structure of learnable content.
   - Strategy – The designer may specify space, time, event, social, and interaction structures that define occasions through which the learner can experience the content structures. The content theorists named above (who represent only a sub-set of all of the theorists who could be named) all have in common the fact that they have made specification

of a theory of strategy structures through which their theory's content structures can be experienced.

- Control – The designer may specify a set of controls (in fact, a limited language) in which communications can be expressed from the learner to the instructional source. This may include a defined language of mouse positions and clicks, a menu language, a limited set of verbal terms, or gestures and natural language expressions. Directly manipulable interfaces such as simulators and virtual worlds pose a special challenge in this respect. Design languages for the creation of control systems receive relatively little attention in the literature, except in the work on the subject of interaction like that of Crawford (2003), but a visit to Google Earth © demonstrates the great variety of control communications possible and desirable. Increasing reliance on non-sequenced forms of instructional strategies like those found in instructional simulations will require theorists to address the subject of control systems more fully in the future.
- Message – Intelligent tutoring systems, and in the future, intelligent Web-based object systems that must compose some portion of the instructional message adaptively at the time of use will have to deal with the structures of message generation and construction systems. They will confront the problem of defining the structural properties of message-making algorithms. Message structures are only abstractions or tokens, as are all of the structures described up to this point. But these abstract structures all converge on the representation domain (layer), which is described next. Examples of discussions of design languages related to messaging systems can be found in the literature of intelligent tutoring (see, for example, Clancey & Shortliffe, 1984).
- Representation – The designer may specify a set of rules for converting abstract structures from all of the other domains (layers) into representations that have sensory properties. In addition, the rules must specify the coordination and synchronization of message elements delivered in different media formats (Mayer, 2001). Design languages for composing and creating representations themselves are so numerous and so present in the literature of instructional design as to prohibit exhaustive enumeration. A design language related to a particular type of information-rich graphical illustration can be seen in the books and Web resources created by Tufte (Tufte, online). Representation design languages are by far the most numerous and detailed because the representation domain (layer) of designs is the first non-abstract domain and the one most noticed by even the most inexperienced instructional designers.
- Media-logic – The designer may specify the structures of execution by which representations are enacted for the learner. Live instructors require directions for conducting interactions, for posing and managing the environment for solving problems, and for providing coaching, feedback, and other support functions of instruction. Automated delivery systems also require directions and logic for providing the same functions. Design

languages for media-logic can bee seen partly in development software manuals. Design languages for live instructor activities are currently conflated theories of coaching, interaction management, problem-based instruction tutoring, and so forth and deal with the *manner and means* of execution of basic instruction-related acts by the instructor.

- Data management – The designer may specify data structures and data processes for the collection, storage, analysis, interpretation, and reporting of data resulting from learner interactions. It is these data that make possible adaptivity of instruction to the individual. Design languages for this complex domain are also described in the literature of intelligent tutoring systems.

3. *Decomposition of design problems in terms of artifact functions and sub-functions (domains, layers) allows the designer to concentrate on sub-problem solutions in detail while at the same time relating sub-problem solutions to the whole*. According to Schön (1987):

> Each move [tentative decision during design] has consequences described and evaluated in terms drawn from one or more design domains. Each has implications binding on later moves. Each creates new problems to be described and solved. Quist [a designer] designs by spinning out a web of moves, consequences, implications, appreciations, and further moves. (p. 57)

4. *Within each sub-problem domain, additional decomposition is possible*. This method of problem localization promotes design modularization. Baldwin and Clark (2000) describe the application of functional design decomposition and its implications for modularization of designs. Their tracing of the history of computer designs is a story of increasing modularity that Baldwin and Clark claim is the foundation of the economic success of the modern computer industry and the key factor responsible for its explosive growth. Brand (1994) illustrates the practical benefits of this kind of design modularization by describing contrasting styles of building design: a style in which design layers are modularized and can change over time independently, and a less-desirable style in which design layers are intermixed and in which changes to one part of the design can result in the destruction of other parts as well. At present, most instructional designs inter-mix design domains in such a way that graceful aging of individual layers of the design and their independent replacement is impossible. Consequently, most instructional designs have a short half-life and are difficult and costly to modify.
5. *For each domain or layer of the design thus defined, many design languages already exist, and new design languages can be created that provide terms appropriate to the solution of sub-problems within that domain*. Schön (1987) describes:

> It is not difficult to see how a design process of this form might underlie differences of language and style associated with the various schools of architecture. Designers might differ, for example, in the priorities they assign to design domains at various stages of

> the process. They might focus less on the global geometry of buildings, as Quist does, than on the site or on the properties and potentials of materials. They might let the design depend more heavily on the formal implications of construction modules. Their governing images might be framed in terms of building character, and they might allow particular precedents to influence more frankly the order they impose on the site. But whatever their differences of languages, priorities, images, styles, and precedents, they are likely to find themselves, like Quist, in a situation of complexity and uncertainty that demands the imposition of an order. From whatever sources they draw such an initial discipline, they will treat its imposition on the site as a global experiment whose results will be only dimly apparent in the early stages of the process.
>
> (p. 65)

Benefits to the Design Process

Benefits of many kinds accrue to the design methodology from the above view of design architecture. According to Gibbons and Rogers (Gibbons & Rogers, Submitted):

> The specific layers of a design evolve and change based on their utility to the designer, according to a number of factors that include design constraints, design criteria, resources, tools, new technology, new construction methods, available designer skills, and designer awareness. Each design includes its own unique combination of layers at the most detailed level. At the most detailed level, layers are created or destroyed according to the decisions and dynamics of a given project.

In general, the design process within this view comes to consist of design by successive constraint placement (Gross et al., 1987; Stokes, 2006) more than it is adherence to a process. Despite process views of design which represent the prevailing doctrine, successive constraint placement is probably a more accurate description anyway of what actually takes place in design projects. An example may show why this view is almost inescapable.

It is common for design problems to be given to a designer by a client with particular constraints already imposed. The client may specify a particular delivery medium or may require a particular instructional strategy to be used. This corresponds to certain commitments having been made within certain design domains (layers) as we described them above. A process approach to design would dictate design steps to be taken in a systematic fashion to complete the project.

However, without violating the general outlines of the process approach, it is easy to see that an examination of the design problem in the light of domains or layers of the problem reveals layers within which those constraints are placed. It is possible using the interaction of layer designs described by Schön above to trace the implications of these existing constraints to design decisions among the individual layers. Certain decisions that would normally be executed during a process may be already constrained, whereas other decisions (some involving process steps) may be made irrelevant. Each constraint placed, either by pre-decision or by the designer's own decision, cascades to constrain the decisions that are necessary or possible within other layers. Therefore, selection of a video medium will have the immediate effect of imposing constraints on some strategy, message, control, representation, media-logic, and data management layer decisions. If the computer medium is pre-selected by constraint, different constraints are rippled to the other layers, and a completely different set of decisions is presented to the designer.

This interaction of layer decisions is an important factor in everyday design-making that process approaches neglect. Designing in terms of layers allows the designer not only to apply traditional processes as they are appropriate, but also to reconfigure the design process to the requirements of the individual project. It allows the designer to tailor an order of decision-making within and between the layers and sub-layers that might be somewhat different than what might be dictated by standard process models.

Other practical benefits that accrue from the layered approach are as follows:

- Modularization of the design itself – Brand's description of building designs (Brand, 1994) demonstrates the value of creating designs in layers that are relatively independent, interacting only at defined interface points. Different layers are allowed to age at different rates, and changes or updates to one layer can be made without destroying the functions of other layers.
- Sharing of layer-related design tasks among design team specialists – As delivery systems increase in sophistication, so do the possible designs for the medium, and so does the range of skills required to design and develop a product. Early involvement of disparate skill sets into a design project is highly desirable to take advantage of judgment and design conceptions that involve specialized areas of the design. Considering the design as a layered structure more clearly defines tasks that can be assigned to specialists, enabling them to participate earlier in a way that balances attention to detailed decisions with concerns for the integration of the whole design.
- Identification of the minimum design decisions essential to allow early initiation of prototyping and testing cycles – Schrage (1999) describes the value of early and rapidly cycled prototyping as a means of refining the design problem and fitting design solutions within their context of use.

Benefits in the Application of Theory to Designs

Gibbons and Rogers (Gibbons & Rogers, Submitted) describe another benefit of conceiving the architecture of designs in terms of layers and the design languages that are related to them:

> Within the context of this view of [layered] instructional design theory, we propose that an instructional theory can be described as a set of specialized, mutually-consistent design languages containing defined terms that are distributed across multiple design layers. This insight unifies the concepts of design layers and instructional theory and, more importantly, shows the relationship between instructional design theory and

> instructional theory. Design theory provides the structural framework within which specific instructional theories can be analyzed and compared. Instructional theories dwell within a framework of layers…

Instructional theories can be viewed as collections of reserved terms selected or created by theorists – terms that pertain to elements used within different domains (layers) by that theorist for the solution of design problems. For instance, the primary categories of cognitive apprenticeship described by Collins et al. (1989) are Content, Method, Sociology, and Sequence. They define the Content category in terms of four types of knowledge whose differing structures designers should consider facilitating with their designs. This clearly corresponds to the content layer described in design layering theory. The remaining categories specify structures a designer would arrange so that interactions, social context, and ordering of interaction events can provide the learner access to and beneficial experience with the content elements. These three categories therefore correspond to three different sub-layers within the strategy layer.

Likewise, across 20 years and 4 editions of *The Conditions of Learning* Gagné described 4 versions of a learning objective taxonomy. Each of the categories in the taxonomy suggests to the designer a type of learning content. Therefore, Gagné's taxonomy – and the numerous other taxonomies created during the same time period – represents content layer design languages, and each type within the taxonomy represents a design language term. In addition, Gagné's nine events of learning represent structures for segmentation of instructional experience. They are strategic structures, and the events represent terms in a strategic design language.

These examples show that the theory of design layering can provide a common framework for analyzing, examining, and comparing instructional theories. Using it, it quickly becomes evident that different theorists choose certain layers as key focal points for their theories and minimize or remain silent about terms that might be associated with some others.

Moreover, it also becomes evident that theorists can concentrate exclusively on a particular layer: Mayer (2001) establishes a set of privileged terms within the representation design layer. Crawford (2003) does the same for the control layer, at the same time describing useful terms that can be associated with the strategy layer. The anthology of classroom observation category systems compiled by Simon and Boyer (1974) can be seen in this light as a collection of taxonomies containing design language terms associated with several layers pertinent to the description of live instruction. As already mentioned, software manuals for development tools contain the terms of the design language associated with the particular tool. A study of the terms contained in a single manual of this type reveals that there are actually several sub-languages associated with every tool, including a language made up of terms describing the development environment itself (for instance, "stage" and "actor"), one describing the elements manipulated and arranged within that environment (for instance, "library object" and "property") to form a product, and usually one describing special scripting languages that function within the context provided by the tool's controlling metaphor. These terms must be matched with the designer's terms that describe actions and activities that fall outside the province of the language of the tool but which are necessary for the creation of the designer's intended interactions (demonstrations, practice occasions, etc.).

Because the terms of design languages can be related to both practical decisions during design and theoretical structures, the principle of design languages explains one way in which theory enters designs. Rather than expecting a single instructional theory to provide an adequate basis for an entire design, we should expect that numerous theories might be called upon. Indeed, if a designer normally makes decisions within most or all of the layers for a given design, the designer can justify the design at a much more detailed level than was possible before. With analysis at this level of detail, it may become apparent which areas of a particular design have a sound theory basis and which do not. Design layers also provide a framework that allows the designer to select and integrate theories that pertain to different layers, mixing and matching them and becoming aware of which theories are compatible and which amplify the effects of which others. Researchers should find that exploration of the layers and correlation of existing theories with them will identify areas of design for which additional theoretical attention is needed.

Conclusion

We have outlined a theory of design architecture that we feel represents a step forward toward our ability to describe what happens, or rather what can happen, at the moment of design. As we proposed at the beginning, we believe this approach can be used to improve the consistency and quality of designs, facilitate communication about designs and theories, and allow designers to work efficiently in design teams and with greater mutual understanding. It may suggest functionalities for advanced design tools and may also be a useful framework for introducing new designers to the languages of design they will use.

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Robust Designs for Scalability

Jody Clarke and Chris Dede

Abstract One-size-fits-all educational innovations do not work because they ignore contextual factors that determine an intervention's efficacy in a particular local situation. Identifying variables within the intervention's setting that represent important conditions for success and summarizing the extent to which the impact of the intervention is attenuated by variation in them can provide prospective adopters of the innovation a better sense of what level of effectiveness they are likely to enjoy in their own particular circumstances. This study presents a research framework on how to conduct such an analysis and how to design educational innovations for scalability through enhancing their adaptability for effective usage in a wide variety of settings. The River City MUVE, a technology-based curriculum designed to enhance engagement and learning in middle school science, is presented as a case study.

Keywords Educational innovations · Adaptability · Scalability · Engagement · Learning · Heuristics · Dimensions of scale · Sustainability · Robust design · Instructional design · Instructional technology · Technology infrastructure · Multi-user virtual environment (MUVE) · Ruggedization · Professional development · K-12 · Teacher ownership · Collaboration · Sustainability

Introduction

"Scaling up" involves adapting an innovation successful in a local setting to effective usage in a wide range of contexts. In contrast to experiences in other sectors of society, scaling up successful programs is very difficult in education (Dede, Honan, & Peters, 2005). For example, the one-size-fits-all model does not fit when scaling up in education because a pedagogical strategy that is successful in one particular classroom setting with one particular group of students

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frequently will not succeed in a different classroom with different students. Research findings typically show substantial influence of contextual variables (e.g., the teacher's content preparation, students' socio-economic status) in shaping the desirability, practicality, and effectiveness of educational interventions. Identifying variables within the intervention's setting that represent important conditions for success and summarizing the extent to which the impact of the intervention is attenuated by variation in such variables can provide prospective adopters of the innovation a better sense of the level of effectiveness they are likely to enjoy in their own particular circumstances. In addition, this type of analysis can help designers improve the robustness of their innovations by developing "hybrid" versions optimized for success in particular types of settings.

In this chapter, we discuss a research framework for how to design for scale in education. As a case study, we offer our research on the River City MUVE curriculum, a technology-based innovation designed to enhance engagement and learning in middle school science. Our intention in presenting these ideas is to provide an analytic framework that can be used to document and compare the impact that various contextual factors have on the success of an intervention across various projects. Heuristics from such analyses may aid designers in developing treatments more effective and scalable, particularly in inhospitable settings. Our suggestions are intended to help policymakers, practitioners, and researchers anticipate the level of resources that might reasonably be invested in scaling up an innovation for effectiveness in a particular context.

In the sections that follow, we first document the importance of designing educational innovations for scalability and making informed judgments about the suitability of an innovation for a particular context. Next, we present a conceptual framework for depicting various dimensions important for scalability. Then, we identify critical contextual features that research documents are important in the effectiveness of technology-based educational interventions. Following this, we describe quantitative analytic methods for determining the attenuation of an intervention's effectiveness by local variation in its conditions for success. With an overall model established for research on scalability, we present early results of applying this framework to a particular case, our River City curriculum. We then discuss implications for robust design that retains effectiveness under inhospitable conditions. Finally, we discuss conclusions and implications for further research.

The Importance of an Innovation's Scalability

Numerous studies have documented that it can be difficult to scale up promising innovations from the fertile, greenhouse environments in which they were conceived to the barren contexts that exist in schools with poor facilities, overwhelmed teachers, and struggling students (Dede et al., 2005). Adapting a locally successful innovation to a wide variety of settings – while maintaining its effectiveness, affordability, and sustainability – is even more challenging.

In general, the more complex the innovation and the wider the range of contexts, the more likely a new practice is to fail the attempt to cross the chasm between its original setting and other sites where its implementation could potentially prove valuable (Moore, 1999). In other words, scalable designs for educational transformation must avoid what Wiske and Perkins (2005) term the "replica trap": the erroneous strategy of trying to repeat everywhere what worked locally, without taking account of local variations in needs and environments. Without advances in design for scalability and in the assessment of an innovation's suitability for a particular context, education will continue to waste substantial resources implementing interventions that fail despite promise shown elsewhere.

Dimensions of Scale

In the context of innovations in teaching/curriculum, Coburn (2003) defines scale as encompassing four interrelated dimensions: depth, sustainability, spread, and shift in reform ownership. "Depth" refers to deep and consequential change in classroom practice, altering teachers' beliefs, norms of social interaction, and pedagogical principles as enacted in the curriculum. "Sustainability" involves maintaining these consequential changes over substantial periods of time, and "spread" is based on the diffusion of the innovation to large numbers of classrooms and schools. "Shift" requires districts, schools, and teachers to assume ownership of the innovation, deepening, sustaining, and spreading its impacts. We propose a fifth dimension to extend Colburn's framework, "evolution." "Evolution" is when the adopters of an innovation revise it and adapt it in such a way that it is influential in reshaping the thinking of its designers. This in turn creates a community of practice between adopters and designers whereby the innovation evolves.

Viewing the process of scaling from a design perspective suggests various types of activities to achieve scale along each dimension:

- *Depth:* evaluation and research to understand and enhance causes of effectiveness
- *Sustainability:* robust design to enable adapting to inhospitable contexts
- *Spread:* modifying to retain effectiveness while reducing resources and expertise required
- *Shift:* moving beyond "brand" to support users as co-evaluators, co-designers, and co-scalers
- *Evolution:* learning from users' adaptations to rethink the innovation's design model

In particular, design for *sustainability* centers on the issue of contextual variation and involves designing educational innovations to function effectively across a range of relatively inhospitable settings (Dede, 2006). This is in contrast to models for effective transfer of an innovation to another context that involve partnering with a particular school or district to make that setting a conducive site for adapting a particular design. Scalability into typical school sites that are not partners in innovation necessitates developing interventions that are "ruggedized" to retain substantial efficacy in relatively barren contexts, in which some conditions for success are absent or attenuated. Under these circumstances, major aspects of an innovation's design may not be enacted as intended by its developers. While all the dimensions above relate to designing to scale, this study focuses on the sustainability dimension and robust design.

We do not expect that interventions created for use in multiple settings through robust-design strategies will outperform an intervention designed for specific classrooms that have all the necessary conditions for success. Similarly, a biotechnologist would not expect to design a plant strain specifically tailored to arid climates that in typical contexts somehow also outperforms those strains that have evolved for more ideal conditions of moisture. The strengths of ruggedized interventions are likely weaknesses under better circumstances; for example, high levels of support for learner help and engagement that aid unengaged pupils with low prior preparation could well be intrusive overhead for better-prepared, already motivated students. We are currently conducting design-based research on our River City MUVE curriculum (described later in the chapter) to explore whether robust design can produce the educational equivalent of plant strains tailored to harsh conditions that are productive where the usual version of that plant would wither and die.

However, the robust-design approach has intrinsic limits, as some essential conditions that affect the success of an educational innovation cannot be remediated through ruggedizing. As an illustration of an essential condition for success whose absence no design strategy can remediate, for implementations of the River City MUVE curriculum in some urban sites, student attendance rates at classes typically averaged about 50% prior to the intervention. Although attendance in science class improved by 60% during the implementation of the curriculum, an encouraging measure of its motivational effectiveness through robust design, clearly the curriculum nonetheless had little value for those students who seldom came to school during its enactment. Further, in the shadow of high-stakes testing and accountability measures mandated by the federal *No Child Left Behind* legislation, persuading schools to make available multiple weeks of curricular time for a single intervention is very hard. Essential conditions for success such as student presence and district willingness to implement pose challenges beyond what can be overcome by the best robust designs.

However, design-based researchers can potentially still get some leverage on these essential factors. For example, as we will discuss later, the River City MUVE curriculum is engaging for students and teachers, uses standards-based content and skills linked to high-stakes tests, and shows strong outcomes with sub-populations of concern to schools worried about making adequate yearly progress across all their types of students (Dede, Clarke, Ketelhut, Nelson, &

Bowman, 2005). These capabilities help surmount issues of student involvement and district interest, giving our intervention traction in settings with low student attendance and a focus on test-preparation.

Identifying Critical Contextual Features

Leveraging the sustainability dimension of scale involves identifying critical contextual features of the design's effectiveness and testing for their interaction with the treatment. How does one determine these conditions for success? What type of data collection is necessary? Based on relevant theory, research, and practice, we are developing a taxonomy of critical contextual variables for technology-based educational innovations (Nelson, Ketelhut, Clarke, Dieterle, Dede, & Erlandson, 2007). In order to build this taxonomy, we are drawing both from the professional literature for practitioners on technology integration (www.ncrel.org/engauge/intro/intro.htm) and from the research literature (empirical studies, theoretical, meta-analyses, evaluations) on the types of factors that investigators have identified as crucial for their technology-based innovations.

For example, we examined all of the studies of educational interventions published between 2002 and 2004 in three leading educational technology journals (*Journal of Learning Sciences, Journal of Educational Computing Research*, and the *Journal of Science, Education, and Technology*), as well as other prominent work in the field (Waxman, Lin, & Michko, 2003; Russell, Bebell, & O'Dwyer, 2003; Means & Penuel, 2005; Pearson, Ferdig, Blomeyer, & Moran, 2005), compiling a list of the variables included in the analyses. We are triangulating these various sources and approaches and have developed the following "work-in-progress" list of contextual variables:

Student Level Variables

- Developmental level (i.e., age)
- Socio-economic status (SES)
- Race or ethnicity
- Gender
- Level of general education (i.e., grade level in school)
- Previous academic performance (includes achievement scores, GPA, class ranking)
- Absentee record
- Teacher expectation of performance
- Major (if higher education)
- Affective measures (e.g., level of engagement and self-efficacy)
- Technology familiarity and fluency (includes level of comfort or anxiety, technology self-efficacy)

- Collaboration skills (for innovations involving group work)
- Population of students (general population, special ed)
- Students' home technology access and usage

Teacher Level Variables

- Years of teaching experience
- Academic specializations (e.g., certified in science)
- Professional development related to the innovation
- Support related to the innovation
- Technology familiarity and fluency
- Teacher's Pedagogical Beliefs
- Teacher's Beliefs about using technology in classroom
- Teacher Demographic Characteristics
- Teacher ownership of content/making personally relevant to students
- Teacher comfort level using innovation
- Teachers' assessment that activities are congruent with the content of standards and high-stakes tests

Technology Infrastructure Conditions

- Access to educational materials:
- Location of technology (lab outside classroom, lab in classroom, computer cart brought in, students' school laptops)
- Reliability and quality of technology (machine level, network/server connection reliability)
- Access to technology equipment
- Type of technology used (personal computers, networked laboratories, multimedia, and others)

School/Class Variables

- School characteristics (e.g., public/private)
- Type of class schedule (rotating, block)
- Length of unit: amount of time students have to use technology
- Type of class (honors, remedial, college prep)
- Sample size (number of students/classes/teachers)

Administrative/School Level Culture Variables

- Support for teachers from an administrator who is positive about the program and can help garner resources, reduce institutional barriers (such as securing transportation to study sites), and showcase activities
- Support and mentoring from other teachers

By identifying features within the intervention's context that represent important conditions for success and summarizing the extent to which the effect of the intervention is sensitive to variation in each (e.g., how each feature interacts with the treatment), prospective adopters of the innovation will have a better sense of its likely overall effectiveness in their particular circumstances. Also, policymakers will gain a better sense of which innovations are most promising in their potential for adaptability to a wide range of settings, and researchers can contrast the scalability of various types of innovations, thereby attaining insights into how to improve design and implementation. In order to summarize the extent to which the intervention is sensitive to contextual variables, we propose utilizing a scalability index, calculated for comparability across projects parallel to current measures such as effect size.

Developing a "Scalability" Index for Innovations

The establishment of the Education Sciences Reform Act of 2002, in addition to creating the U.S. Education Department's Institute of Education Sciences (IES), is fostering a shift in what kinds of evidence constitute "proof" of an innovation's effect. A report for IES prepared by the Coalition for Evidence-Based Policy (2003) states that "evidence-based" research entails randomized controlled experiments that report the size of a treatment's effect (effect size). There are various statistical methods for calculating an effect size (ES). The most common is Cohen's *d* (Cohen, 1988), where the difference between the mean of two groups is divided by the pooled standard deviation of the two groups:

$$d = \mathrm{M}_1 - \mathrm{M}_2 / \sigma_{\text{pooled}}$$

Cohen (1988) offered conventional definitions of the ES for describing the magnitude of the effect (p. 40):

Small: $d = 0.20$
Medium: $d = 0.50$
Large: $d = 0.80$

It is important to note that in the social sciences, even the most successful interventions have small effect sizes (Light, Singer, & Willett, 1990).

However, publishing one overall effect size does not allow policymakers to determine the likely effectiveness of the innovation in their local setting where students, teachers, and resources may vary from the conditions for success of the innovation, ideal conditions under which its effect size was calculated. Simply reporting this metric does not provide decision makers and designers with enough information to leverage the sustainability dimension of scale. Therefore, we are currently exploring the utility of a "Scalability Index" that estimates the relative sensitivity of innovations to attenuation in various dimensions that represent their conditions for success. For example, if the effect of an innovation was found to have an interaction with class size (number of students in the classroom), then an index that summarized the extent to which the innovation's effect was attenuated when used in classrooms with more than, say, 30 students would provide valuable input into decision making. The proposed index would summarize, along each dimension of its major conditions for success, the degree to which the educational effectiveness of the design is robust to a shortfall in that dimension.

We are currently developing analytic strategies for creating our proposed "Scalability Index" based on Cohen's (1988) f^2 standardized framework for estimating the size of the effect associated with interactions. We are applying this to estimate the interaction between a treatment and a condition for success. One approach to calculate Cohen's f^2 is to use the R^2 statistic, which measures the proportion of the variation in the outcome that is explained by the predictors or predicted by the predictors in a regression model. The f^2 is also a measure of proportion in variation of the regression model with the contextual variables and their interaction with treatment:

$$f^2 = \frac{R^2_{\text{full}} - R^2_{\text{reduced}}}{1 - R^2_{\text{full}}}$$

One can compare the *square root* of the f^2 index to Cohen's conventional definitions of the ES for describing the magnitude of the effect, as discussed earlier (Cohen, 1988, p. 40).

Using this method, conditions for success that generate large values of the f^2 statistic in interaction with the treatment would suggest that the impact of the intervention is very sensitive to this particular condition for success. We plan to present these scalability index data in tables where the effect size of the interactions between treatment and various conditions is provided (presenting the square root of the f^2 statistic). Then, decision makers can carefully consider the impact of the particular condition before implementing the intervention at new sites. In addition, designers can use this information to develop "hybrid" versions of the innovation where the design is flexible enough to be optimized for success under various conditions.

River City MUVE as a Case Study

Leveraging the sustainability dimension of scale involves identifying critical contextual features of the design's effectiveness and testing for their interaction with treatment. In order to design for scale, designers should develop flexible models with variants adapted to a spectrum of implementation conditions. As a case study illustrating this design strategy, we offer our own research on the scaling up of River City, a technology-based curriculum.

River City is a multi-user virtual environment (MUVE) designed to teach middle school science (http://muve.gse.harvard.edu/rivercityproject/). MUVEs enable multiple simultaneous participants to access virtual contexts, interact with digital artifacts (such as online microscopes and pictures), represent themselves through "avatars," communicate with other participants and with computer-based agents, (see Fig. 1) and enact collaborative learning activities of various types (Nelson, Ketelhut, Clarke, Bowman, & Dede, 2005). When participants click on an object in the world, the content appears in the right hand interface (see Fig. 2).

The River City curriculum is centered on skills of hypothesis formation and experimental design, as well as on content related to national standards and assessments in biology and ecology. Middle school students travel back in time to the nineteenth century and use their twenty-first century knowledge and skills to help the Mayor figure out why the residents of River City are getting sick.

Three different illnesses (water-borne, air-borne, and insect-borne) are integrated with historical, social, and geographical contents, allowing students to develop and practice the inquiry skills involved in disentangling multi-causal problems embedded within a complex environment (Ketelhut, Clarke, Dede, Nelson, & Bowman, 2005). Students work in teams of three or four to develop and test their hypotheses about why residents are ill. Students learn about and use the tools of scientists as part of their scientific exploration. For example,

Fig. 1 This photo shows a student avatar, Jody, talking to Nurse Peterson, a River City resident

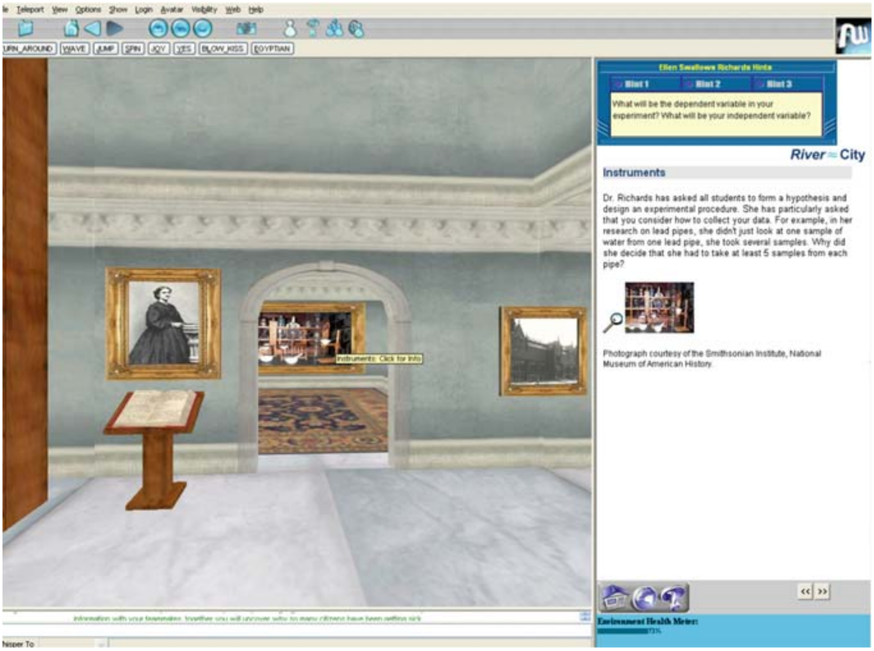

Fig. 2 This picture depicts the view of River City 3-D environment on the *left* and the web-based content on the *right side* of the screen

they can use the virtual microscope to take water samples (see Figs. 3 and 4) from one of the water sampling stations in the city.

Research Design

Utilizing design-based research strategies, we have conducted a series of studies in which we explored the types of learning that MUVEs appear to foster. We present results from these studies to illustrate how we identified contextual factors and what design elements we modified to overcome any barriers. At varied intervals, we implemented different treatments of River City based on alternative theories of how people learn: guided social constructivism, expert mentoring and coaching, legitimate peripheral participation (communities of practice), and levels of guidance. For a detailed description of these different studies and treatments, please see Nelson, Ketelhut, Clarke, & Bowman (2005) and Clarke, Dede, Ketelhut, & Nelson (2006). To date, we have worked with over 70 teachers and 6,000 students primarily in urban public middle schools with high proportions of ESL low SES students. This chapter focuses on a sub-sample of 7 teachers and more than 600 students who implemented River City in fall 2004.

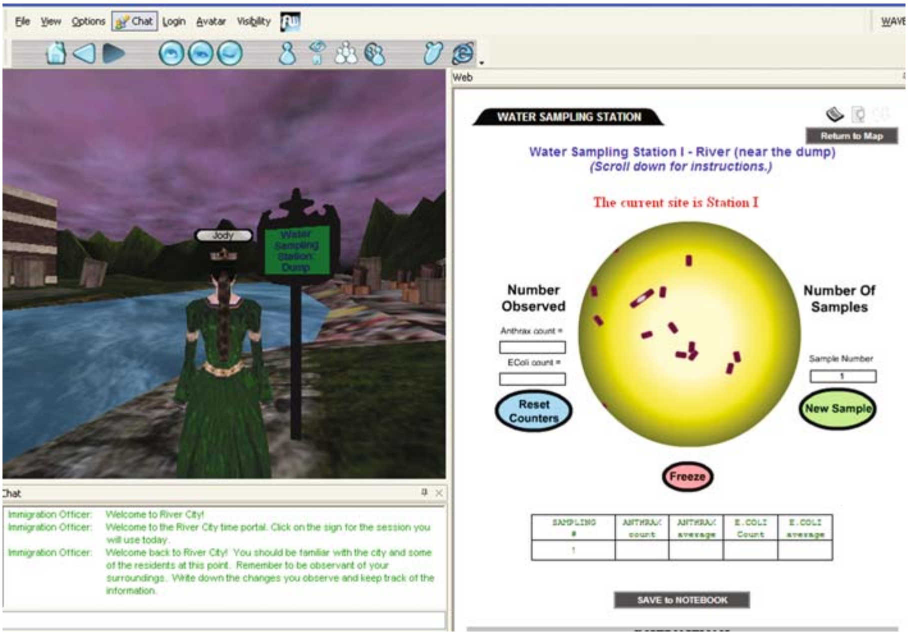

Fig. 3 Virtual microscope tool used for water sampling. Students click on the "Water Sampling Station" sign in the 3-D virtual world and a microscope appears in the right hand interface with moving *Escherichia coli*

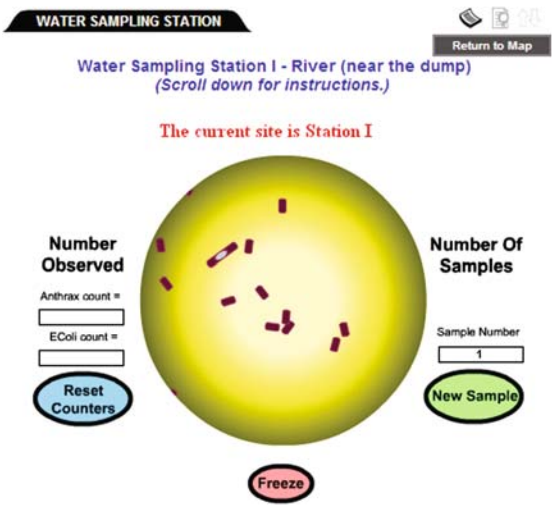

Fig. 4 Close up of microscope. Students click "Freeze" and count the number of *E. coli* and Anthrax in the water. After counting up the *E. coli*, students can take a new water sample and a new count

We employed quasi-experimental design strategies where students were assigned to either treatment or control at the classroom level. Within the treatment classrooms, students were randomly assigned to one of our learning variants at the student level. The control curriculum was similar in pedagogy and content, yet delivered via paper-based curriculum. Each teacher was offered both the computer-based treatments and the control.

We collected demographic data on students from teachers, including age, prior science grades, free and reduced lunch status (as measure of SES), native language, race, gender, reading level, attendance, and teacher expectation of students along five dimensions: content mastery, motivation, behavior, absence, and technology mastery. (Please note that some teachers did not supply this information; therefore, we were unable to test for interactions between some of these variables and treatment. We discuss later how we have modified our implementation to prevent this lack of data in the future.)

Students were administered an affective measure that was adapted from three different surveys, Self-Efficacy in Technology and Science (Ketelhut, 2004), Patterns for Adaptive Learning Survey (Midgley et al., 2000), and the Test of Science Related Attitudes (Fraser, 1981) pre- and post-interventions. This modified version has scales to evaluate students' science efficacy, thoughtfulness of inquiry, science enjoyment, career interest in science, etc. At the end of this survey, they were also asked about their technology access and usage outside of school. To assess understanding and content knowledge (science inquiry skills, science process skills, biology), we administered a content test pre- and post-interventions, with sections modified from Dillashaw and Okey (1980).

Teachers were administered questionnaires pre- and post-interventions that asked about their years of teaching experience, academic specializations, professional development in technology, technology fluency and familiarity, pedagogical beliefs and practices around science and technology, comfort level with technology, comfort with project, and opinion of level of support provided by our research team.

The backend architecture of the MUVE environment is a database. This database has an event table that captures detailed moment-by-moment individual student activity in the environment, such as which residents they talked to, what pictures they clicked on, how long they spent in a given location. These data-rich files were captured for all students in the experimental treatment. In addition, as a final performance demonstration, all students completed a report to the Mayor of River City that explained their experiment and findings.

The quantitative data were analyzed with SAS using multiple regression techniques. Checks for linearity and homoscedasticity were performed. No violations were detected. A significance level of $p < 0.10$ was used.

At its core, the evaluation of the sensitivity of an intervention's impact to select contextual conditions is a question of statistical interactions. In evaluating the sensitivity to the conditions for success, one asks the following: Is the effect of the intervention dependent on the selected contextual conditions? Is the intervention more effective for children of lower SES, or higher? In our research, such questions were addressed by the inclusion of the statistical models of interactions between the treatment and its conditions for success. We present results from these studies to illustrate how we identify contextual factors and what design elements we modify to overcome any barriers.

Findings

Results from this implementation supported earlier findings that students in the River City treatment are engaged in scientific inquiry and in higher-order thinking skills (see Nelson et al., 2005; Clarke et al., 2006). We found a positive relationship between students' starting self-efficacy in general science and their post-test score. The magnitude of this relationship was greater for students in the River City treatment. We did not find any significant differences between the four River City treatments and therefore present analyses looking at the River City treatment versus the control curriculum. As seen in Fig. 5, the impact of the River City treatment on students' post-test score, controlling for SES, differed depending on students' gender and entering self-efficacy in general science. SES explains variance in the outcome, total post-test score (t = –7.53***), but does not have a statistical interaction with the treatment. Therefore SES is not a condition for success but is included as a control variable

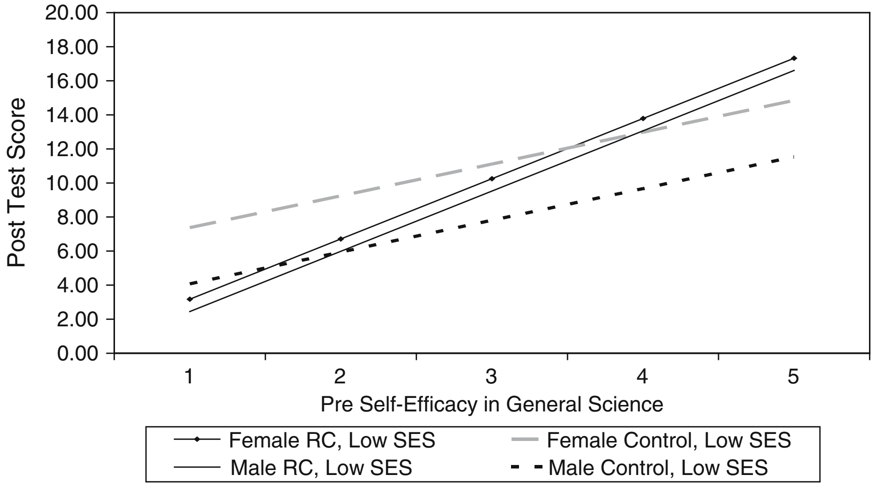

Fig. 5 Effect of treatment on post-test score, controlling for male, SES, and pre-self-efficacy in general science ($n = 362$)

because it helps to explain the variance. For example, for students with low SES, girls in the control who entered the project with low self-efficacy in general science performed better on the post-test than girls in River City with similar low self-efficacy in general science, on average. However, for students with low SES, girls in River City who entered the project with high self-efficacy (~4) outperformed everyone on the post-test score, on average. Within each of the two treatments, for students with low SES, girls outperformed boys on the post-test, on average.

The results for students with high SES are parallel but slightly higher (the interaction between SES and treatment was not significant). The interactions between some of the contextual variables and treatment suggest that there are conditional factors that may be considered conditions for success when implementing the River City project.

We are just starting to explore and identify these contextual factors. For the sake of space, in this chapter we focus on student level variables from our working list presented above. In order to know whether or not these variables were conditions for success, we performed analyses to test whether or not they had a statistically significant interaction with treatment. Table 1 summarizes the results of the tests for interactions and the extent to which the effect of the intervention is sensitive to variation in each. Column 1 lists the student contextual variables, and column 2 states whether or not there was a statistical interaction. Statistical interactions were measured through multiple regression analysis;

Table 1 Student contextual variables and their statistical interaction with treatment

Student level contextual variables	Interaction with treatment	Parameter estimate (t value, p value)	$\sqrt{f^2}$
Socio-economic status (SES)	No	$t = -0.06$	
Race	No	$t = 0.28$	
Gender	Yes	$t = 1.69\sim$	0.13
Native English speaker	No	$t = -0.81$	
Level of general education (i.e., grade level in school)	No	$t = 0.70$	
Enjoyment of science	Yes	$t = 2.84$**	0.24
Self-efficacy in general science	Yes	$t = 2.11$*	0.38
Career interest in science	Yes	$t = 3.89$***	0.32
Thoughtfulness of inquiry in Science	No	$t = 0.92$	
Science inquiry	No	$t = 1.60$	
Internet access at home	No	$t = 0.60$	
Use chat programs	No	$t = 0.30$	
Play computer games	No	$t = 0.53$	
Play video games	No	$t = 0.12$	

Please note we did not detect an interaction between treatment and any grade level, but due to space we only present the t value for the interaction between seventh grade and treatment.

$\sim p<0.10$; *$p<0.05$; **$p<0.01$; ***$p<0.001$.

column 3 presents the *t* value and *p* value of the parameter estimate of the interaction in the model. Column 4 presents the square root of the f^2 index, calculated from the R^2 statistic, using the formula explained above.

As can be seen in the rows 4, 8, 9, and 10 of column 2, only four of the student contextual variables represent important conditions for success, as determined by statistical interaction with treatment in this sample. According to Cohen's conventions, all of the effects of the interactions with treatments in this sample are "small." This is not surprising. As mentioned above, in education, the effect sizes of even the most successful interventions tend to be "small" (Light et al., 1990).

Looking at column 4, we can create an index from least to highest sensitivity, where Gender is the least sensitive (0.13) and "Entering Self-Efficacy in General Science" is the most sensitive (0.38). In addition to providing insights on student learning in the project, these findings are helping us to discover which factors we need to modify in order to improve the scaling up of our design. As a result of naturalistic variation among teachers, students, technology infrastructures, and school settings, we have an opportunity to assess how factors related to each of these variables affect learning outcomes. In the following section, we discuss how this analysis of the conditions for success is helping us to make our design more robust, so that we can scale our innovation across a wide variety of educational settings.

Designing Framework for Scalability and Ruggedization

Developing a design for scalability into contexts in which "important, but not essential" conditions for success are weakened or lacking requires adding options that individualize the innovation when parts of its intended enactment are missing. As described above, we are identifying conditions for success likely to be attenuated in many contexts and evolving the curriculum's design to allow for individualization that enhances effectiveness under those circumstances.

In prior research, (Clarke et al., 2006) we identified four factors important in the enactment of the River City curriculum and discussed how we were evolving the curriculum's design to allow for individualization that enhances the effectiveness under those conditions. Our design process has evolved, and therefore the following section provides an updated look of these conditions for success combined with new findings presented above. Our first two conditions for success are concerned with teacher level conditions around teacher ownership of content and teacher comfort level using innovation. Our discussion for how we made the design robust for these conditions focuses on the infrastructure and backend architecture of the design. Our other conditions for success focus on student conditions for success and design features of the curriculum.

Teacher Conditions for Success

Professional Development

Through design-based research, we have been testing various ways of providing professional development for teachers (Clarke et al., 2006). We provided online training for some teachers, but found that most of them did not access it. We also knew that, as we scaled, we would not be able to provide just-in-time advice for teachers. Therefore, we are now testing how a "train the trainer" model of professional development scales. In this model, members of our research team provide professional development for trainers. Each trainer works with up to ten teachers in a district, providing professional development and monitoring their implementations. The trainer is available to provide "just-in-time" support for teachers and also serves as the "eyes and ears" of the research team in classrooms where the project is implemented.

Teacher Ownership and Comfort Level

We have found that integrating the River City project, a technology intensive project, pushes the limits of teacher's comfort level. In the post-surveys and interviews, some teachers have expressed that they felt more comfortable with the control curriculum because they felt like they had more "control." We have been searching for ways to provide teachers with more autonomy and empowerment in the River City project, a condition that we feel leads to success of the implementation. Our result is a "Teacher Dashboard" that provides teachers with all the tools and mechanics necessarily to successfully implement the River City project. This dashboard houses numerous resources and functions under one location (Web page), so that teachers only need to create a single book mark in their Internet browser (the site is password protected).

Through the "Teacher Dashboard", teachers can now create student accounts and passwords for the River City program. In the past, teachers did not always fulfill their obligations to provide us with the demographic data we need in order to look for various conditions for success. Being able to determine the conditions for success relies heavily on the collection of appropriate data. In the results presented above, missing data on student prior academic achievement, reading scores, and demographics led to sample size about 25% smaller than it should have been. Therefore, with the "Teacher Dashboard", when the teacher creates each student account, they must enter demographic data about each student. After creating a class of students, they then assign the students to teams of three. In the past, we created student accounts and randomly assigned student teams. These two steps are meant to provide teachers with more control over using the project with their students and also make the project easier to scale as the teachers rely less on the research team. We no longer receive any emails from teachers regarding student logins or complaints about team assignments.

As students move through the River City project, they advance through six different worlds chronologically that represent different seasons: October 1878, January 1879, April 1879, July 1879, the control world (controlled portion of their experiment) and their experimental world (testing their experiment). This allows them to collect data on change over time in River City. When students first enter the River City program, they enter a "time portal" and then click on the world to which they wish to travel back in time. While students are supposed to travel back and work through the project chronologically, this has not always been the case. Teachers have had very little control over the ability to make sure students are in the right world during a given class period. Therefore, we added a "world access" feature that is now available in the "Teacher Dashboard." Teachers have the option to set world access at the class or student level. While this might seem minute, early feedback indicates that it has made a difference in terms of teachers feeling as though they have control over the curriculum and students' chronological movement through it. Most importantly, this feature is customizable – teachers do not even have to use it.

Our last infrastructure-related design for scale is another customizable feature meant to provide teachers with more control over student learning in the project. As mentioned above, the backend of the River City environment is a database. We use these data files to track students' learning trajectory in the world. However, until now teachers have never had access to these data. While we encourage teachers to review student lab books and keep up with student progress via written work in the project, teachers have had little detailed knowledge about what each student is doing in the program itself. Inside River City, students work in teams and communicate with their team via a text-based chat. We are in the process of adding a feature to the "Teacher Dashboard" that allows teachers to run reports on the "team chat" at the student, team, and/or class level. A report will be generated that shows the world, avatar names, and team chat of the students. This optional feature will allow teachers to monitor their students' progress (whether they are actually on task) and language (whether or not they are using bad language). Again, this feature will be customizable for teachers and optional in usage.

In addition to these modifications in the architecture of the design, we have added resources such as "Individualized Professional Development" documents and "Day-by-Day" lesson planning for teachers to use as resources and "quick guides." We have also added short videos (less than a minute) that model what students are supposed to do each day in the curriculum. For example, before students enter "January 1879," a teacher can show students the "January 1879 Video." The video reminds students what they have been doing in the project and connects it to what they will be doing in January – providing context and building a continuum in the curriculum. Each video has a similar look and feel. All footage was captured from the River City environment, and each video starts with the Mayor of River City (an avatar from the environment) talking to the students. These videos were created as a model for teachers of how to introduce each day's lesson, or as an introduction for students before they begin their daily activities.

Student Affective Conditions for Success

Our next set of robust-design strategies is concerned with conditions for success measured at the student level. We have found that students enter the project with varying levels of engagement in science, self-efficacy in general science, background knowledge, and career interest in science. While we have designed our project to engage all students, we hope to reach students who are not engaged in science, don't feel good about their ability to do science, and have a history of low academic performance in science. Through design-based research, we have been studying ways not only to engage our target student population, but also to maintain engagement for students who are already performing well in science. We are developing three different strategies to meet these needs: powers, pedagogical agents, and roles.

Powers

Similar to features of videogame play that reward experiences and accomplishments by giving participants special powers, we have designed a system of powers that reward student learning and exploring in the River City environment. These powers provide students with access to further curricular information that will help them more deeply understand the spread of disease in River City. As mentioned above, students travel through River City chronologically. They enter the city during four different seasons, collecting information about the spread of disease in the town. Next, they then develop a hypothesis based on their research and design an experiment to test their hypothesis. They then go back into River City (the control and experimental worlds) to test their experiment. Accompanying each world is a list of curricular objectives that guide students through the inquiry process. These curricular objectives have been modified into activities such that completion of them leads toward the attainment of powers.

For example, we want students to explore the different areas of River City and gather information about how the three diseases are more prevalent in different areas of the city. Therefore, in the spring world (April), some of the requirements to obtain powers involve visiting a certain location and talking to the residents in that location, or clicking on pictures or objects in that location. As an illustration, students learn a lot of important information when they visit the hospital. Once inside, they can talk to Nurse Patterson, Doctor Aaron Nelson, review the admissions records, and click on pictures that provide historical information about nineteenth century hospitals. Therefore, as a requirement for one step toward achieving powers for this given world, we have backend Boolean statements that scan the database and register whether at least one team member has visited the hospital and interacted with a resident, object, or picture. Just like in a videogame, students are not told the requirements for powers, nor are they told that they exist. However, they are presented with the curricular objectives in their lab books and use the lab book to guide their discovery. Once a combination of team members has completed the specified curricular tasks, they earn “powers” and are teleported to a secret mansion in the city.

This secret mansion contains extra curriculum and is only accessible for teams of students who have earned “powers” by completing the curricular objectives. The first power earns students access to the first floor entryway of the building. Each successive world’s powers is another floor of the building; so students who achieve powers in, for example, April 1879 will have access to the hallway, the second story and the third story. Therefore, if students missed attaining powers in some previous level of the world, they can make up the missed learning by later attaining powers in a different level.

The “powers” for April 1879 involve access to curriculum that presents students with a historical look at the tools of scientists from the nineteenth century to 2005. The third floor of the mansion is a museum, and a sign welcomes students to click on the various tools. For example, they can click on an 1880 version of a microscope and then on a modern day microscope to see how much the tool has evolved and enables us to detect such things as microbes. The River City world has modern day microscopes that enable students to take water samples, but having this extra curriculum provides some insight about why the scientists in the nineteenth century were not able to see diseases caused by bacteria.

Students learn that, as better and better microscopes were invented, scientists were able to see microbes more clearly. However, even with the modern microscope, it isn’t possible to see inside the body. Students learn about a modern tool that was invented that allows doctors and scientists to see into the body: a CAT scan. Students can click on the names of patients listed in the April hospital records to see what a CAT scan of their lungs looked like. When names are clicked on, if the person has tuberculosis (one of the three diseases in River City), then the CAT scan shows a diseased lung. If they do not have tuberculosis, then the CAT scan shows a healthy lung.

These powers are engaging for students while still providing rich content that furthers their knowledge. Powers illustrate an adaptation of the curriculum to aid students with low motivation to succeed. We are now starting studies to determine if the inclusion of powers makes River City more effective in settings where many students are turned off to school.

Pedagogical Agents

In addition to maintaining student engagement, we have found it important to help some students gain more self-efficacy in their ability to do science as they move through the project. Therefore, we are in the process of developing pedagogical agents: “wise fools” that will work alongside students as they move through the River City curriculum. These “wise fools” will ask students questions that encourage them to reflect on their learning. Each team will have one “wise fool” working alongside them, agents who know to which of the residents team members have talked and on what artifacts and objects they have clicked. Using strategies from the literature on metacognition (Brown, 1987; Campione, 1987; Schoenfeld, 1992; White & Frederiksen, 1998) and reciprocal teaching (Palincsar & Brown, 1984, 1985; Palincsar, 1986; Palincsar, Ranson, & Derber, 1989), the “wise fools” will ask students for information and encourage student learning along the way. They will also offer information about the project (in addition to the guidance and hints developed by Nelson, 2005). We hypothesize that these conversations with the “wise fools” will help students learn and increase their self-efficacy as they move through the project.

Roles and Collaboration

Collaboration is an important element in students’ learning in River City. However, close examination of log files and interviews with students reveals that many students struggle with collaboration (Clarke, 2006). Therefore, through design-based research we plan to develop curricular strategies that will encourage students to collaborate with their teammates. Under these conditions, each particular teammate will have access to different levels of information. In order to fully understand what is causing the problems, the entire team will need to pool their information and findings. For example, one teammate might ask a particular resident how they are. The resident will respond differently depending on the team member who asks the question. To teammate A, the resident might respond, “I have a slight fever and my stomach aches. I was feeling fine yesterday, and was playing near the bog with my friend Emily.” However, the resident might respond differently to teammate B, “I have a slight fever and my stomach aches.” Or to teammate C, “I am sad. I could not go and play near the bog today with my friend Emily because I am sick. We have been playing by the bog all week.” Just like in the real world, who you are determines the type of response you might receive from a person. We hypothesize that including these roles will engage students in trying to figure out what each of their teammates have discovered and foster richer collaboration via jigsaw pedagogy.

Conclusion

Bringing a technology innovation to scale in education requires a design that is flexible enough to be used in a variety of contexts and robust enough to retain effectiveness in settings that lack its conditions for success; this may involve developing variants that are the equivalent of hybrid plants designed for inhospitable locales. Designing an innovation for sustainability and scale is a multistage process. One must first identify possible contextual variables that lead to conditions for success of the innovation. Next one must collect data on these various conditions. Then one must test for the statistical interaction between these conditions and the treatment. Finally, one can develop variants of the design model effective under these conditions. As an illustration, through design-based research strategies we are determining what contextual variables constitute conditions for success in implementing River City and developing heuristics for robust variants in settings where those factors are attenuated or missing.

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Externally Modeling Mental Models

David H. Jonassen

Abstract Meaningful learning, as opposed to reproductive learning, is active, constructive, intentional, authentic, and collaborative. When learners engage in meaningful learning, they naturally construct mental models. When learners collaborate, they naturally construct group mental models. One method for engaging learners in meaningful learning is to have them construct computer-based models that externalize their mental models. Using tools such as databases, concept maps, expert systems, spreadsheets, systems modeling tools, microworlds and simulation tools, teachable agents, computer conferences, and hypermedia, learners can construct models of domain knowledge, problems, systems, semantic structures, and thinking processes.

Keywords Modeling · Mental models · Meaningful learning · Authentic contexts · Collaboration · Cognitive residue · Structural knowledge · Performance/procedural knowledge · Activity-based knowledge · Conversational/discursive knowledge · Social negotiation · Computer-based modeling · Microworlds · Modeling systems · Simulations · Instructional technology

What is Meaningful Learning?

Jonassen, Howland, Moore, and Marra argue that meaningful learning occurs when learners are active, constructive, intentional, cooperative, and working on authentic tasks. Human learning is a naturally *active* mental and social process. When learning in natural contexts, humans interact with their environment and manipulate the objects in that environment, observing the effects of their interventions and constructing their own interpretations of the phenomena and the results of the manipulation and sharing those

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interpretations with others. Through formal and informal apprenticeships in communities of play and work, learners develop skills and knowledge that they then share with other members of those communities with whom they learned and practiced those skills. In all of these situations, learners are actively manipulating the objects and tools of the trade and observing the effects of what they have done.

During that activity, learners are continuously *constructing* their interpretations of their actions and the results of those actions. What happens when I do this? What does that mean? What does that mean to me? Rather than rehearsing what something means to the teacher or the curriculum developers, meaningful learning focuses on what phenomena mean to the learner. That requires active manipulation of ideas and artifacts. Humans naturally construct meaning. In order to survive all these years, humans have always had to construct meaning about the world.

Learning is most meaningful when it is *intentional*. All human behavior is goal directed (Schank, 1994). That is, everything that we do is intended to fulfill some goal. When learners are actively and willfully trying to achieve a cognitive goal, they think and learn more because they are fulfilling an intention. The intention may not be initially expressed by the learner, but it must be accepted and adopted by the learner in order for learning to be meaningful. When learners evaluate their learning in terms of their intentions, they understand more and are better able to use the knowledge that they have constructed in new situations.

Most contemporary theories of learning agree that meaningful learning requires a meaningful task, and the most meaningful tasks are those that emerge from or are at least simulated from some *authentic context*. When learners wrestle with authentic problems, they are not only better understood, but also more consistently transferred to new situations. Rather than abstracting ideas in rules that are memorized and then applied to other canned problems, we need to teach knowledge and skills in real life, useful contexts and provide new and different contexts for learners to practice using those ideas. And we need to engage students in solving complex and ill-structured problems as well as simple problems (Jonassen, 1997). Unless learners are required to engage in higher-order thinking, they will develop oversimplified views of the world.

Finally, meaningful learning is often *collaborative*. Humans naturally work in learning and knowledge building communities, exploiting each others' skills and appropriating each others' knowledge. In everyday contexts, humans naturally seek out others to help them to solve problems and perform tasks. Schools generally believe that learning is an independent process, so learners seldom have the opportunity to "do anything that counts" in collaborative teams despite their natural inclinations. However, relying solely on independent methods of instruction cheats learners out of more natural and productive modes of thinking and learning. Collaboration usually requires conversation among participants. Learners working in groups must socially negotiate a common understanding of the task and the methods they will use to accomplish it. That is, given a problem or task, people naturally seek out opinions and ideas from others, so conversation should be encouraged.

It is important to point out that these characteristics of meaningful learning are interrelated, interactive, and interdependent. That is, learning and instructional activities should engage and support combinations of active, constructive, intentional, authentic, and cooperative learning because they are synergetic. Learning activities that represent a combination of these characteristics result in even more meaningful learning than the individual characteristics would in isolation.

It is ironic to point out that meaningful learning typically occurs in natural contexts and seldom in formal educational contexts. The inculcation of ideas, values, and socially accepted beliefs too often prevents natural learning experiences. However, there exist formalized learning activities that do engage meaningful learning, just as there are teachers who have for years engaged students in meaningful learning. In this chapter, we argue that technologies can and should become the toolkit for meaning making. Technologies afford students the opportunities to engage in meaningful learning when used as tools for constructing, testing, comparing, and evaluating models of phenomena, problems, the structure of ideas, and the thought processes engaged in their creation.

What is the Cognitive Residue from Meaningful Learning?

What is left after learning meaningfully, that is, what evidence is that someone has learned meaningfully, that is, what is the cognitive residue (Salomon, Perkins, & Globerson, 1991)? The result of meaningful learning is a model of the phenomena that have been explored and manipulated. Learners begin constructing their own simple mental models to explain their worlds, and with experience, support, and more reflection, their mental models become increasingly complex as they interact with the world in more complex ways. Even more complex models will enable them to reason more consistently and productively about the phenomena they are observing. Humans are natural model builders.

Unfortunately, the concept of mental model is conceptually rich but operationally problematic. For instance, how do you assess someone's mental model, the cognitive residue of what they have learned? That is a particularly difficult question, because there is so little agreement on what mental models are. There are many conceptions of mental models, beginning with Johnson-Laird (1983) and Gentner and Stevens (1983). All of these various conceptions have resulted in what Rips (1986) refers to as "mental muddles." Are mental models semantic models, simulations, procedural knowledge in the form of inference rules, or what? We believe that mental models are all of these, that is, they are rich, complex, interconnected, interdependent, multi-modal representations of what someone or some group knows. These models can function far more effectively in their totality.

Individual Mental Models

Individual, internal mental models consist of multiple, interdependent, and integrated representations of some system or set of phenomena. In order to represent an individual's mental model, several forms of evidence are needed, including structural knowledge, procedural knowledge, reflective knowledge, spatial/imaginal knowledge, metaphorical knowledge, executive knowledge, and a host of beliefs about the world (Jonassen & Henning, 1999).

Structural Knowledge

Structural knowledge is the knowledge of the structure of concepts in a knowledge domain and can be measured in a variety of ways (Jonassen, Beissner, & Yacci, 1993). Industrial and organizational psychologists tend to regard structural knowledge measures as the definition of mental models (Kraiger & Salas, 1993). Using structural knowledge methods to portray mental models assumes that they can be represented as networks of nodes and links. While we believe that networks of interconnected constructs underlay mental models, they cannot function adequately as the sole means of representation. They provide only the semantic structure for mental models. We develop a mental model about processes and their underlying assumptions that include an associative structure, but is not merely an accumulation of entities.

Performance/Procedural Knowledge

In order to assess someone's mental model, it is essential that she or he uses the model to operate on the part of the environment that is being modeled. Utilizing an individual's model to test its predictive and explanatory power is perhaps the most essential component of the model. Jonassen and Henning (1999) assessed think-aloud protocols while individuals solved a troubleshooting problem. In addition to providing performance problems that need to be solved, learners should be required to articulate their plan for solving the problem, and they should be observed on how well they adhere to the plan, what strategies they use for dealing with discrepant data and events, and finally what kinds of generalizable conclusions they can draw from the solution.

An increasingly common method for assessing mental models is the teach-back procedure, in which learners or users are asked to teach another learner (typically a novice) how to perform certain tasks or how to use a system. Students often produce a variety of representations, such as a list of commands, verbal descriptions of task components, flow charts of semantic components, descriptions of keystrokes (van der Veer, 1989).

Image of System

Wittgenstein (1922) described propositions as imaginal models of reality. Most humans generate mental images of verbal representations. Mental models definitely include mental images of the system being explored. So, it is important to elicit the learner's mental image of a prototype of the system s/he is constructing. Requiring learners to represent their visual model or system model can provide rich data about any learner's understanding (Taylor and Tversky, 1992).

Metaphors

In addition to imaginal representations, humans naturally tend to relate new systems to existing knowledge, often by associating them with other physical objects. Metaphors are important means for understanding peoples' mental models because the metaphors contain imaginal, structural, and analogical information about their understanding.

Executive Knowledge

It is not enough to have a runnable model of a domain or process, but in order to solve ill-structured problems it is essential to know when to run which model. Knowing when to activate mental models allows the learner to allocate and apply necessary cognitive resources to various applications. So it is necessary to assess the strategies that learners generate for solving problems.

Beliefs

Beliefs about the world may be the most compelling components of mental models. Beliefs are the reflected and unreflected assumptions lying in parts of the model. Belief represents the space where we connect the model with our own person (Durkheim, 1915). As theories emerge in humans, they rely on their own, fairly materialistic views of the world. These natural ontologies for representing phenomena provide coherent but often incorrect views of the world. The revolutionary conceptual change that is required for learners to give up these theories and adopt a more principled ontology of beliefs is very difficult (Chi, 1997). So, assessing an individual's beliefs about the phenomena they are representing is necessary for uncovering misconceptions or distorted conceptions of the world.

Collaborative Group Mental Models

Group or collaborative mental models are those that are socially co-constructed by groups of individuals who are collaboratively focused on the same meaningful task. Group or team mental models also consist of multiple representations of some system or phenomenon. In order to represent a group's mental model, several forms of evidence need to be assessed, including activity-based knowledge, social or relational knowledge, conversational or discursive knowledge, and the artifacts that are used and produced by the group.

Activity-Based Knowledge

Activity theorists believe that activity and consciousness are one and the same. We cannot think without acting or act without thinking (Engeström, 1987; Jonassen, 2000). The simplest inference from this belief is that in order to understand what learners know, watch what they do. That observation may include visible elements of behavior that can be observed without intervening in the process or invisible elements that must be inferred with invasive procedures such as think-alouds or teach-backs. These methods provide invaluable evidence about the nature of the mental models that learners are constructing. And because that activity is so often performed collaboratively, the combined activity can provide evidence about what the group knows. Team mental models are constructed in collaboration, requiring an extensive amount of discursive knowledge (described next).

Conversational/Discursive Knowledge

Social negotiation of meaning is a primary means of solving problems, building personal knowledge, establishing an identity, and most other functions performed in teams. The most common initial step in problem solving is to contact a colleague and ask, "What do you think?" The primary medium of discourse is stories. These stories provide contextual information, function as a format for problem solution, and also express an identity. Stories provide a natural flow of conversation among the collaborators. Stories often contain emotional overtones about the experiences, especially about first experiences as a performer (Jonassen & Henning, 1999).

Social/Relational Knowledge

Individuals in many everyday contexts experience ambiguity about their status within the larger organization (Barley & Bechty, 1994). Members of collaborative groups often build strong social relationships with other members of a well-defined community of practice. Examine most organizations and you will find that members of work groups often socialize as well as function professionally. The social and relational knowledge that is fostered by this socialization helps to establish a group identity that helps to resolve ambiguity about their status within the organization.

Artifactual Knowledge

There is knowledge or cognitive residue evidenced in the artifacts that learners produce. That is, when students produce artifact, especially while modeling systems, there is extensive evidence of their thinking in the products. Artifacts can also serve as discourse markers. Objects that are left around intentionally can serve as important lessons to others.

Summary

An important goal of all educators and especially technology educators is to help learners to develop their theories about how the world works, that is, to construct mental models. In the following section, we describe how to employ technologies in that effort.

Modeling Mental Models

Science and mathematics educators (Confrey & Doerr, 1994; Frederiksen & White, 1998; Lehrer & Schauble, 2000; White, 1993) have long recognized the importance of modeling in understanding scientific and mathematical phenomena. In this chapter, we attempt to expand upon that belief system by arguing that modeling is an essential skill in all disciplines, that is, it is an essential cognitive skill for meaning making in all domains. We also argue that in addition to modeling domain knowledge (the primary focus of math and science education work to date), learners can apply modeling skills in different ways: by modeling domain knowledge, by modeling problems (constructing problem spaces), by modeling systems, by modeling semantic structures, and by modeling thinking processes (i.e., cognitive simulations). In addition to distinguishing between what is modeled, we also distinguish between kinds of modeling systems and their affordances for supporting the construction of mental models. Why is modeling so important?

The mental models that most people have constructed as their personal of socially negotiated representations of phenomena in the world (scientific, social, cultural, political, and even phenomenological) are naive, uninformed, and often inconsistent with established theories. While developing personal theories and integrating them into mental models may be a natural cognitive process, but that does not imply that people are very good at it. Personal theories and mental models are replete with misconceptions and inadequate conceptions. Learners should be supported in their construction of more complete and viable models of the phenomena they are studying. What often makes human models weak and oversimplified is that they fail to identify relevant factors and are not dynamic, that is, they do not represent change in factors over time.

Modeling as a process is also important because it is one of the most conceptually engaging cognitive processes that can be performed. Solving design problems are potentially more engaging, however, technologies to date better afford modeling processes than designing activities which are less constrained and more complex.

The underlying assumption of this chapter is that constructing computational models of the world using computer-based modeling tools can serve to externalize learners' mental models of the phenomena that they are studying. Several researchers have demonstrated the relationship between modeling and mental models (Frederiksen & White, 1998; Mellar, Bliss, Boohan, Ogborn, & Tompsett, 1994; White, 1993). The most effective way to support the construction of mental models is to engage learners in using a variety of tools for constructing physical, visual, logical, or computation models of the phenomena. Most of these tools are technology-mediated. Jonassen (2000) has argued that constructing models is among the most effective and engaging ways to use technologies focusing on critical thinking engaged by modeling with technology. In this chapter, we are explicitly focusing on the effects of modeling on mental model construction. That is, building physical and computational models using technologies provides learners the opportunities to operationalize and externalize their mental models. It is important here to now distinguish between learners using or interpreting models, which are common in classrooms, and building models.

There are two basic ways that models can be used to facilitate mental model construction, manipulating model-based environments and building models that represent the learner's understanding. In this chapter, we will describe a number of environments like ThinkerTools, EcoBeaker, Agent Sheets and other microworlds, where students can input data and manipulate the system characteristics, testing the effects of theory manipulations. Most simulations and microworlds are of this type. They are exploratory environments that afford learners the opportunities to test the causal effects of manipulations, but the underlying model that defines the system parameters is not revealed to the learner. Learners can infer parts of the model through manipulating the environment. These are known as black box systems. The model is in a black box that cannot be seen.

The second kind of modeling system that can be used to facilitate mental model construction is the modeling tool. These tools provide a framework for describing content that constrains the ways that learners view and understand the system. Systems modeling tools, expert systems, and semantic modeling tools (described in detail later) are glass box systems, where learners can, not only investigate the underlying model, but can also change it. In fact, the learners construct the model. While it is conceptually important to distinguish model-using from model-building, no research exists that compares the cognitive effects of model-using versus model-building. We hope to provide some of that research in the future and believe that the cognitive residue from building models will be significantly greater than from using model-based systems.

What Is Being Modeled

If modeling can aid the articulation of mental models, then learners should learn to model a variety of phenomena. In this section, we will briefly describe the range of phenomena that can be modeled using different tools. An underlying assumption is that modeling different phenomena (domain knowledge, problems, systems, semantic structures, and thought processes) is necessary for constructing advanced, complete mental models.

Most of these models are what Lehrer and Schauble (2000) refer to as syntactic models. These are formal models, each of which imposes a different syntax on the learner that conveys a relational correspondence between the model and the phenomena it is representing. The purpose of syntactic models is to summarize the essential function of the system being represented.

Modeling Domain Knowledge

The primary focus of mathematics and science educational use of modeling has been for the purpose of modeling ideas in math and science domains. Learners can use a variety of tools for representing and experimenting with domain concepts. Sometimes those models are physical, functional models of body parts, such as the elbow, with children as young as first graders (Penner, Giles, Lhrer, & Schauble, 1997). More commonly, middle school and high school students are using computer-based modeling tools, such as microworlds, systems modeling tools, or other qualitative modeling tools, to construct their models of scientific systems. For example, Fig. 1 illustrates the use of the microworld, ThinkerTools, for modeling and experimenting with principles related to trajectories in physics. This is an example of a model-using environment where the model is implicit in the environment. In ThinkerTools, the user exerts impulses on the dot prior to launching it. The relationship between the impulses or vector forces on the trajectory of the dots can be explored. In Fig. 1, it appears that the correct vector forces were applied.

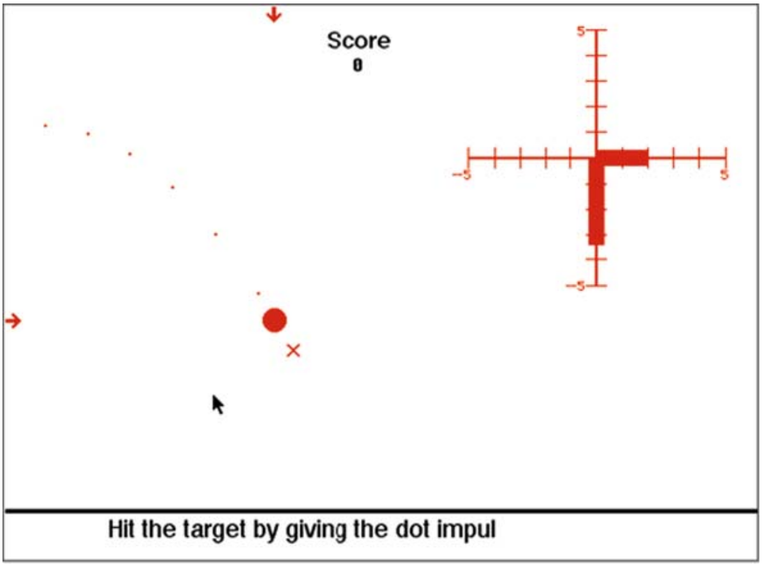

Fig. 1 Modeling principles of trajectories in physics using ThinkerTools

Students can use a wide range of tools to construct models. Figure 2 illustrates geometry principles being modeled in Cabri, a geometry visualization tool from Texas Instruments, similar to Mathematic, MatLab, Geometric Supposer, and many others. In each of these models, students are representing

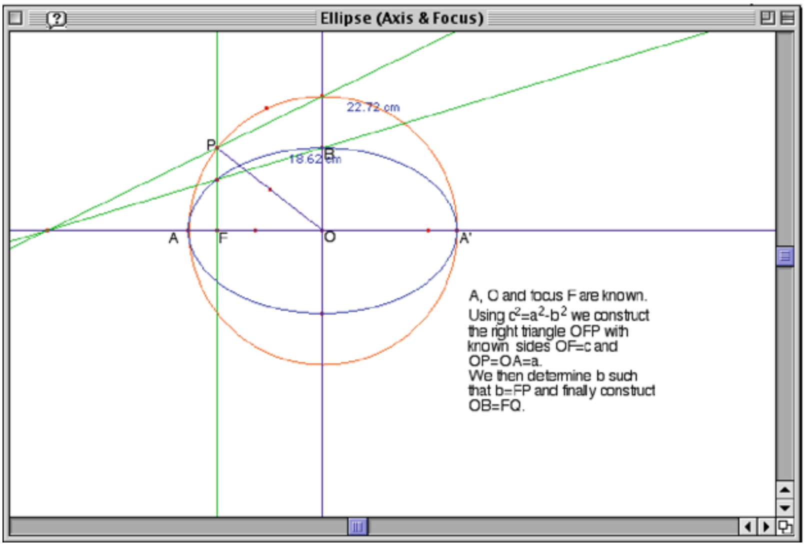

Fig. 2 Cabri geometry model

domain principles that they are studying. The modeling tools enable students to test their mental models of the phenomena they are studying. In both of these examples, however, underlying models of the phenomena are implicit and can be assessed (Spector, Christensen, Sioutine, & McCormack, 2001). The principles are exemplified in the representations. That is, the relationships among the variables are explicitly stated.

Modeling Problems

Another important but unresearched issue is the use of modeling tools for developing explicit models of problems that students are trying to solve. That is, rather than modeling the domain knowledge from which problems are extracted, we suggest modeling the factors and entities on a problem-by-problem basis. When students directly represent problem entities, they are representing the problem space (Jonassen, 2003). It is generally accepted that problems solvers need to construct some sort of internal representation (mental model) of a problem (problem space) in order to solve a problem. These personal problem representations serve a number of functions (Savelsbergh, de Jong, & Ferguson-Hessler, 1998):

- To guide further interpretation of information about the problem,
- To simulate the behavior of the system based on knowledge about the properties of the system, and
- To associate with and trigger a particular solution schema (procedure).

Problem spaces are mentally constructed by selecting and mapping specific relations of the problem (McGuinness, 1986). The underlying assumption of this chapter is that using modeling tools to create physical, visual, or computational models externalizes learners' mental models. Related to problem solving, constructing visual and computational models of problems externalizes learners' internal problem spaces. Constructing models of problem spaces is important for all kinds of problems. As the complexity of the problem increases, producing efficient representations becomes more important; and efficiency of representations is a function of organization, integration, or coherence (McGuinness, 1986).

Although many computer-based modeling tools support the construction of quantitative models of problems, constructing qualitative models of problems is equally, if not more, important. Qualitative representations assume many different forms and organizations. They may be spatial or verbal, and they may be organized in many different ways. Qualitative representations are more physical than numerical. Physical representations of problems consist of entities that are embedded in particular domains (e.g., physics), and the inferencing rules that connect them and give them meaning are qualitative (Larkin, 1983).

Qualitative representations rather focus on the design of processes (system thinking) and the system as a whole of connections/causal relations, quantitative representations rather focus on the numerical value of singular entities within the system and the formulas underlying in the process. Physical versus non-physical representations distinguish more models of the natural (hard) sciences from social sciences/humanities.

Context "This knowledge base is intended to simulate the processes of calculating molar conversions."

Qualitative representations function to:

- explicate information that is stated only implicitly in problem descriptions but is important to problem solution
- provide preconditions on which quantitative knowledge can be applied
- qualitative reasoning supports construction of quantitative knowledge not available initially, and yield a set of constraints that provide guidelines for quantitative reasoning (Ploetzner & Spada, 1998).

In fact, Ploetzner, Fehse, Kneser, and Spada (1999) showed that when solving physics problems, qualitative problem representations are necessary prerequisites to learning quantitative representations. When students try to understand a problem in only one way, they do not understand the underlying systems they are working in. Figure 3 illustrates a qualitative model of a simple stoichiometry (molar conversion) problem in chemistry using an expert system. That is, the learners constructed a production rule system that describes the logic needed to solve the problem. Qualitative representations support the solution of quantitative problems. The best problem solutions may result from the integration of qualitative and quantitative models. That integration is best supported in systems modeling tools, such as Stella, that provide quantitative representations of the relations between problem components expressed qualitatively. Figure 4 illustrates a Stella model of a stoichiometry problem, providing both quantitative and qualitative representations of the problem. In the model in Fig. 4, the main parts of the model are contained in the flows (N20 and H20 production) and the converters (mass NH4N03, total mass, etc.) which the students define by providing numerical values or formulas to describe relationships between the factors. The underlying assumption of systems models is change in the processes over time.

Modeling Systems

Another way of thinking about subject matter content is as systems. Rather than focusing on discrete facts or characteristics of phenomena, when learners study content as systems, they develop a much more integrated view of the world. There are several, related systemic conceptions of the word, including open systems thinking, human or social systems thinking, process systems, feedback systems thinking, systems dynamics, control systems or cybernetics, activity theory, and the most common living systems. All of these conceptions

Context "This knowledge base is intended to simulate the processes of calculating molar conversions."

D1: "You know the mass of one mole of sample."

D2: "You need to determine molar (formula) mass."

D3: "Divide sample mass by molar mass."

D4: "Multiply number of moles by molar mass."

D5: "You know atomic mass units."

D6: "You know molar mass."

D7: "Divide mass of sample by molar mass and multiply by Avogadro's number."

D8: "Divide number of particles by Avogadro's number"

D9: "Convert number of particles to moles, then convert moles to mass"

D10: "Convert mass to moles using molar mass, and then convert moles to molecules using Avogadro's number."

D11: "Convert from volume to moles (divide volume by volume/mole), and then convert moles to moles by multiplying by Avogadro's number."

Q1: "Do you know the number of molecules?" A 1 "yes" 2 "no"

Q2: "Do you know the mass of the sample in grams?" A 1 "yes" 2 "no"

Q3: "Do you know the molar mass of the element or compound?" A 1 "yes" 2 "no"

Q4: "Do you know the number of moles of the sample?" A 1 "yes" 2 "no"

Q5: "Do you want to know the number of molecules?" A 1 "yes" 2 "no"

Q6: "Do you want to know the mass of the sample in grams?" A 1 "yes" 2 "no"

Q7: "Do you want to know the molar mass of the compound?" A 1 "yes" 2 "no"

Q8: "Do you want to know the number of moles of the sample?" A 1 "yes" 2 "no"

Q9: "Do you know atomic mass units?" A 1 "yes" 2 "no"

Q10: "Do you know the volume of a gas?" A 1 "yes" 2 "no"

Rule1: IF q2a1 AND q8a1 THEN D2

Rule2: IF (d1 OR q3a1) AND q2a1 AND q8a1 THEN D3

Rule3: IF q4a1 AND q3a1 AND q6a1 THEN D4

Rule4: IF q3a1 THEN D1

Rule5: IF q3a1 THEN D5

Rule6: IF q9a1 THEN D6

Rule7: IF qq3a1 AND q2a1 AND q5a1 THEN D7

Rule8: IF q1a1 AND q8a1 THEN D8

Rule9: IF q1a1 AND q6a1 THEN D9

Rule10:IF q2a1 AND q5a1 THEN d10

Rule11:IF q10a1 AND q1a1 THEN d11

Fig. 3 Excerpt from expert system rule base on stoichiometry

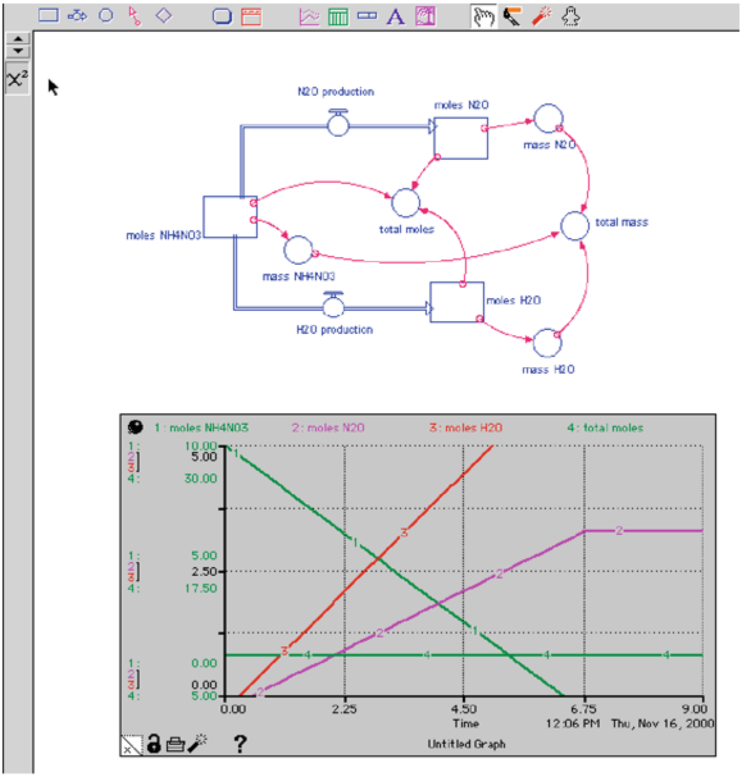

Fig. 4 Systems dynamics model of stoichiometry problem in Stella

share similar attributes, including irreducible wholes, self-producing pattern of organization determined by dynamic interactions among components, interdependent parts, goal-driven, feedback controlled, self-maintaining, self-regulating, synergetic, and teleological. Requiring learners to organize what they are learning into relevant systems that interact with each other provides learners with a much more holistic as well as integrated view of the world. There are a variety of computer-based tools for supporting systemic thinking. Based on systems dynamics, tools like Stella, PowerSim, and VenSim provide sophisticated tools for modeling systems. These tools enable learners to construct systems models of phenomena using hypothetical-deductive reasoning. Students must construct the models before testing them. Figure 5 illustrates a systemic view of the circulatory system constructed with Model-It, a simplified systems modeling tool developed by the HI-CE group at the University of Michigan for junior high school students. This tool scaffolds the identification of relationships among variables. Rather than entering formulae to describe relationships, students must identify the direction of the relationship and the potential effect of one variable on another.

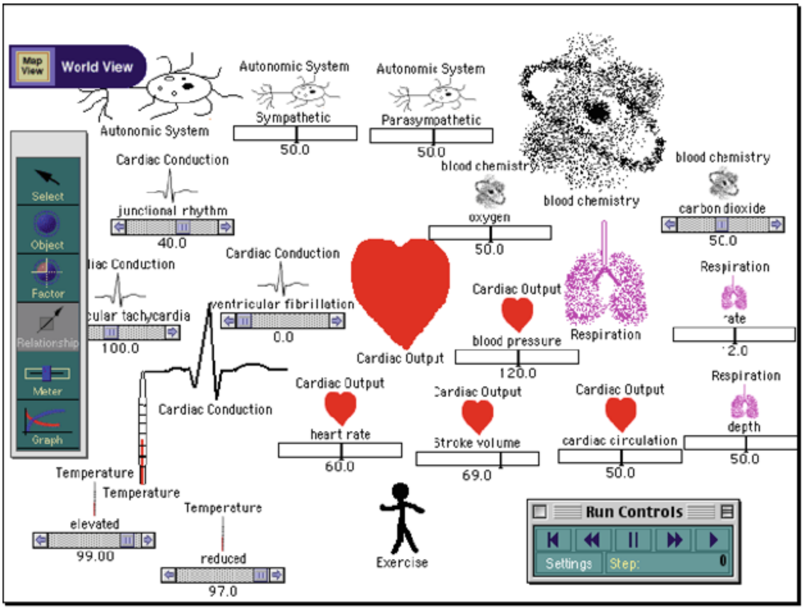

Fig. 5 Modeling the circulatory system with Model-It

Another class of tool enables learner to inductively construct models of systems. Microworlds such as StarLogo, AgentSheets, and EcoBeaker enable learners to construct rules about the nature of the behavior in systems and to immediately test the effects of those rules. Figure 6 models the growth of miniature organisms in environment and to perturb that environment and retest the growth patterns. In this case, the model shows the effects of a hurricane on the growth of Bryzoa. These tools represent a complexity theoretical view of the world, rather than mere systems. That is, they explore the self-organizing nature of phenomena in the world.

Modeling Semantic Structure

It is generally accepted by psychologists that knowledge in long-term memory is organized in a variety of structures, known as cognitive structures or semantic networks. Cognitive structure is "… a hypothetical construct referring to the organization of the relationships of concepts in long-term memory" (Shavelson, 1972, pp. 226–227). These structures describe how concepts are interrelated. These organizations, from a schema theoretical view, provide meaning to concepts. That is, meaning idea is determined by the associations between concepts. While this is but one theoretical interpretation meaning, it is a dominant one that is supported by a number of computer-based tools.

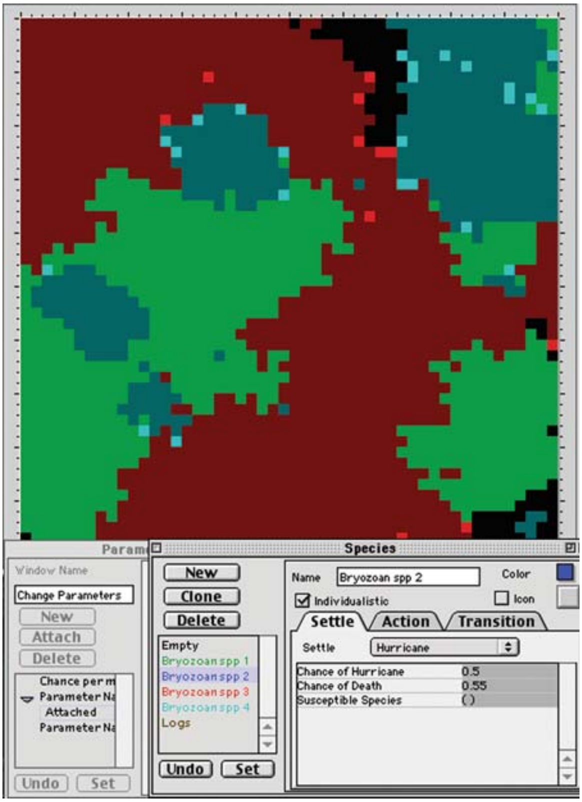

Fig. 6 Modeling the effect of a hurricane on Bryzoan using EcoBeaker

The more popular form of semantic organization tool is the concept mapping or semantic networking tool. The semantic networks in memory and the concept mapping tools that represent them are composed of nodes (concepts, constructs, or ideas) that are connected by links (statements of relationships between the constructs). Figure 7 shows a concept map that is part of a much larger map that addresses British romantic poetry. The central concept is the title of a poem, which is linked to important characteristics of that poem. Clicking on any of the other concepts shows all of the associations to that concept. The aggregation of all of these individual maps is someone's semantic network related to the domain.

Another tool for helping learners to articulate the semantic structure of ideas within a domain is the common database. Databases are used ubiquitously to organize information about every aspect of our lives. They can also be used by learners to organize information that they are studying. Figure 8 illustrates a database about cells created by biology students. This database, including fields about function, shape, location, tissue system, and other attributes of cells,

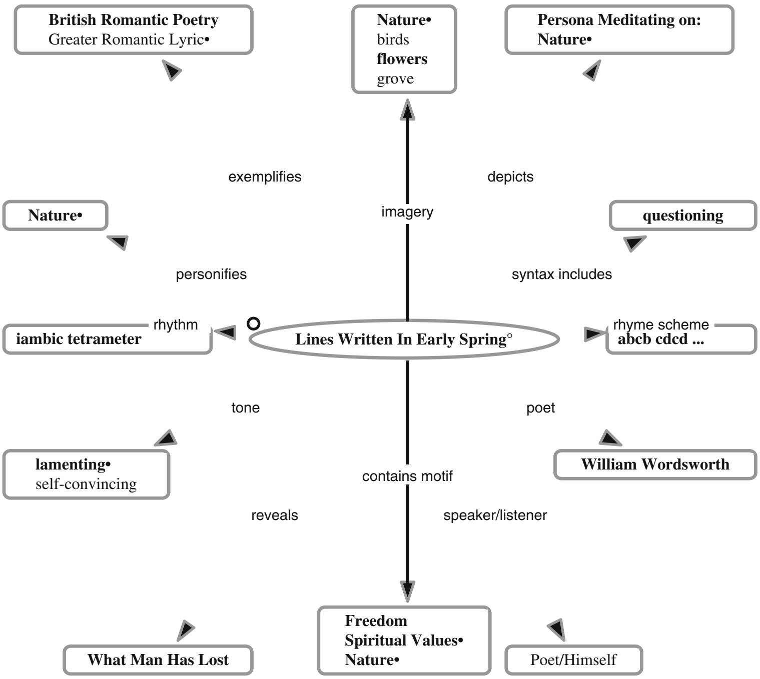

Fig. 7 Concept map or semantic network about a poem

provides a structure for interrelating these attributes. Students can compare and contrast cell types by searching and sorting the database.

What makes modeling semantic structure different from modeling domain knowledge? Semantic nets are clearly a form of representation of domain knowledge. But the tools force students to use organizational formalisms unlike those they normally use. These formalisms explicitly signal the interrelationships between these ideas. They form a semantic foundation for understanding a domain.

Modeling Thinking

Another kind of modeling entails developing models of thinking processes. Rather than modeling content or systems, learners model the kind of thinking that they need to perform in order to solve a problem, make a decision, or complete some other task. That is, learners can use computer-based modeling tools to construct cognitive simulations. "Cognitive simulations are runnable computer programs that represent models of human cognitive activities" (Roth, Woods, & People, 1992, p. 1163). They attempt to model mental structures and human cognitive processes. "The computer program contains explicit representations of proposed

cell type	location	function	shape	related cells	specializatior	tissue syster	associated pr	related disea:	other	growth
Astocyte	CNS	Supply	Radiating	Neurons,	Half of	Nervous			Neuroglia	No
Basal	Stratum	Produce New	Cube,	Epithelial	Mitotic	Epithelial		Cancer		Yes
Basophils	Blood	Bind Imm.E	Lobed	Neutrophil,	Basic,Pos	Connectiv	Histamine,			No?
Cardiac	Heat	Pump Blood	Branched	Endomysi	Intercalate	Muscle	Actin,	Athroscler		No
Chondrobl	Cartilage	Produce	Round			Connectiv	Collagen		Chondroc	Yes
Eosinophil	Blood	Protazoans,	Two	Basophil,	Acid,	Connectiv				No
Ependyma	Line CNS	Form	Cube		Cilia	Nervous			Neuroglia	No
Erythrocyt	Blood	Transport O2,	Disc	Hemocyto	Transport	Connectiv	Hemoglobi	Sickle Cell	Reticulocyt	No
Fibroblast	Connectiv	Fiber	Flat,		Mitotic	Connectiv	Collagen,	Cancer?	Fibrocyte	yes
Goblet	Columnar	Secretion	Columnar	Columnar	Mucus	Epithelial				No
Keratinocy	Stratum	Strengthen	Round	Melanocyt		Epithelial	Keratin			No
Melanocyt	Stratum	U.V. Protection	Branched	Keratinocy	Produce	Epithelial	Melanin	Skin		Yes
Microglia	CNS	Protect	Ovoid	Neurons,	Macropha	Nervous			Neuroglia	No
Motor	CNS(Cell	Impulse Away	Long, Thin	Sensory	Multipolar,	Nervous			Efferent	No
Neutrophil	Blood	Inflammation,	Lobed	Basophils,	Phagocyto	Connectiv	Lysozyme			No
Oligodend	CNS	Insulate	Long	Neurons	Produce	Nervous		Multiple	Neuroglia	No
Osteoblast	Bone	Produce	Spider	Osteoclast	Bone	Connectiv	Collagen	Osteopor	Osteocyte	Yes
Osteoclast	Bone	Bone	Ruffled	Osteoblast	Destroy	Connectiv	Lysosomal	Osteopor		no
Pseudostr	Gland	Secretion	Varies	Goblet	Cilia	Epithelial				No
Satellite	PNS	Control	Cube	Schwann,	Chemical	Nervous			Neroglia	No
Schwann	PNS	Insulate	Cube	Neurons,	Form	Nervous		Multiple	Neuroglia	No
Sensory	PNS(Cell	Impulse to	Long, Thin	Motor	Unipolar,	Nervous	Neurotran		Afferent	No

Fig. 8. Database on cells

ASK: "Why am I studying this material? Assigned = Material was assigned by professor Related = Material is useful to related research or studies Personal = Material is of personal interest"
ASK: "How well do I need to know this material? Gist = I just need to comprehend the main ideas. Discuss = We will discuss and interrelate the issues. Evaluate = I have to judge the importance or accuracy of these ideas. Generate = I have to think up issues, new ideas, hypotheses about the material."

ASK: "How fast of a reader am I?"

CHOICES: slow, normal, fast

ASK: "How many hours do I have to study? None = Less than an hour Few = 1-3 hours Several = 4-8 hours"

ASK: "How many days until class?"

CHOICES Days: more_than_7, 2_to_6,less_than_2

ASK:"How do I compare with the other students in the class? Superior = I think that I am better able than my classmates to comprehend the material. Equal = I am equivalent to the rest of the class in ability. Worse = I am no as knowledgeable or intelligent as the rest of the class."

Fig. 9 Metacognitive factors in cognitive simulation

mental processes and knowledge structures" (Kieras, 1990, pp. 51–2). The primary purpose of cognitive simulations is to attempt to externalize mental processes for analysis and theory building. Most often used by knowledge engineers to construct elaborate tutoring systems, Jonassen has found that even young learners can reflect = on their thinking in order to build these simulations. Jonassen describes the process of constructing a cognitive simulation of metacognitive reasoning using an expert system shell. Figure 9 shows selected factors from that knowledge base. Students were required to reflect on how they used executive control and comprehension monitoring activities while studying for their seminar. Lippert (1988) argued that having students construct small knowledge bases is a valuable method for teaching problem solving and knowledge structuring for students from sixth grade to adults. Learning is more meaningful because learners evaluate not only their own thinking processes but also the product of those processes.

We have also been experimenting with systems dynamics tools for constructing cognitive simulations. Figure 10 illustrates a Stella model of memory (thanks to Ran-Young Hong). Stella is a systems dynamics tool for representing the dynamic relationships between systems phenomena. Both expert systems and systems dynamics tools enable the learners to construct and test the assumptions and functioning of their models.

Types of Model-Based Learning Systems

As can be seen from the previous section describing the aspects of systems that can be modeled, there are many kinds of tools available for modeling a wide range of phenomena. These tools vary in their characteristics, functionality, and

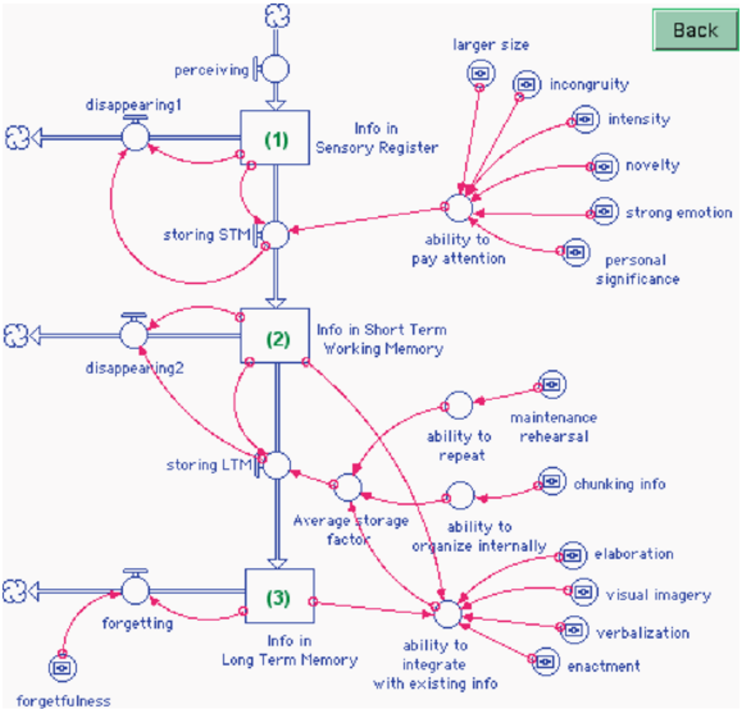

Fig. 10 Stella model of memory

affordances. Each uses a somewhat different structure and syntax for modeling phenomena. Each can be substituted for another, though not always with positive consequences. Different combinations of critical, creative, and complex thinking are engaged by each kind of tool (Jonassen, 2000). We will briefly describe different kinds of modeling tools.

Building Deductive Simulations

A class of systems modeling tools, including Stella, PowerSim, VenSim, and Model-It enable learners to build and test models of closed systems controlled by feedback. Based on systems dynamics, learners build conceptual representation using a simple set of block icons to construct a map of a process: stocks, flows, converters, and connectors (see Fig. 10). Stocks illustrate the level of something in the simulation. In Fig. 10, *info in long-term memory* and *info in short-term memory* are stocks. Flows control the inflow or outflow of material to stocks. *Storing* and *forgetting* are flows. Flows often counterbalance each other, like positive and negative influences in causal loops. For example, *forgetting* is a negative, controlling influence on *info in long-term memory*. Converters convert inputs into outputs. They are factors or ratios that influence flows. *Forgetfulness* is a converter. Converters are used to add complexity to the models to better represent the complexity in the real world. Finally, connectors are the lines that show the directional effect of factors on each other by the use of arrows. These models are dynamic, that is, characterized by action or change in states. So a dynamic simulation model is one that conceptually represents the changing nature of system phenomena in a form that resembles the real thing. These simulations are syntactic representations of reality. What distinguishes these models from the next class is that the model is conceived and implemented before testing. The model is hypothetical/deductive.

This kind of model can also be built using spreadsheets. The model in Fig. 11, for example, was built by students to test the effects of a series of resistors. The model is explicated in the formulae that are entered into each cell. If this model were built by the teacher for students to manipulate and test effects, it would function more as a microworld, where students explore black box simulations.

Building Inductive Simulation Models

Another class of modeling tool uses a more inductive for constructing simulations. Modeling tools like Agent Sheets, Star Logo, and GenScope enable learner to build more open system models of phenomena. Rather than

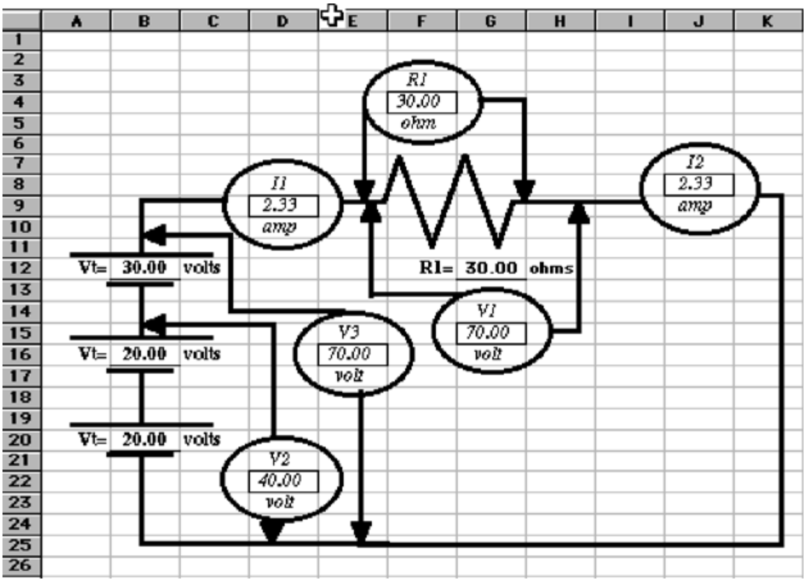

Fig. 11 Resistor series model built in a spreadsheet

identifying all of the components of the model before building it, students use these environments.

Exploring Black Box Models or Simulations

Most simulations that are constructed for student exploration and experimentation do not explicate the underlying model. They enable learners to manipulate variables and test the effects of those manipulations. Students then generate hypotheses about the relationships between variables and further test those. Microworlds, like ThinkerTools (Fig. 1; White, 1993), Boxer (DiSessa & Abeson , 1986), Geometric Supposer (Schwartz & Yerulshalmy, 1987) and others require learners to construct at least an implicit model of system in order to generate hypotheses and test them. They require learners to at least construct a mental model, but not necessary to lead to a visualization of their mental model.

Qualitative Causal Models

Expert systems are artificial intelligence programs designed as simulated experts to facilitate decision making for all sorts of problems. An expert system is a computer program that attempts to simulate the way human experts solve problems – an artificial decision maker. Constructed with facts and a series of IF–THEN rules, the builder must identify all the possible decisions or outcomes, all of the factors that may be involved in each decision, and then constructs the rules that connect all of the possible system conditions with all of the possible conclusions or results. Building expert systems is a knowledge modeling process that enables experts and knowledge engineers to construct conceptual models (Adams-Webber, 1995). While many of the systems modeling and other tools rely on quantitative representations of relationships among factors, experts systems rely on qualitative descriptions of causal relationships.

Semantic Modeling Tools

Tools for representing the semantic relationships within a domain of concepts, such as semantic networking/concept mapping tools and databases, enable learners to represent the semantic associations between domain concepts. These tools, however, are unable to model dynamic, causal relationships, only associational information about a domain of related concepts. These tools provide matrix and spatial representations of concepts and their interrelationships that are intended to represent the knowledge structures that humans store in their minds (Jonassen et al., 1993). Why create semantic networks?

Meaningful learning requires that students connect new ideas to knowledge that they have already constructed. Concept maps and databases help in organizing learners' knowledge by integrating information into a progressively more complex conceptual framework.

Critical Caveat About Modeling Tools

We argued early in this chapter that the cognitive residue of meaningful learning is a model of what is being meaningfully learned. Further, we argued that using or constructing models supports the construction of mental models. If that is so, then we must ask if the models that learners construct possess evidence in the model or in its construction processes of structural, procedural, reflective, imaginal, metaphorical, executive knowledge, and beliefs about that knowledge. Often they do not because the modeling tools that learners use rely on specific kinds of representations. If mental models are underdeveloped as a result of modeling, it may be necessary to use more than one kind of modeling tool to represent phenomena. That is, mental model construction will likely be enhanced when learners use more than one tool to model a domain, problem, system, semantic structure, or thought process. How many tools and which combinations will best facilitate mental model construction will need to be determined by research.

Rationales for Model Construction

Schwarz and White (2005) argue that modeling is fundamental to human cognition and scientific inquiry. They believe that modeling helps learners to express and externalize their thinking; visualize and test components of their theories; and make materials more interesting. We briefly summarize some of the reasons for constructing models to support meaningful learning and mental model construction.

- Model building is a natural cognitive phenomenon. When encountering unknown phenomena, humans naturally begin to construct theories about those phenomena as an essential part of the understanding process.
- Modeling supports hypothesis testing, conjecturing, inferring, and a host of other important cognitive skills.
- Modeling requires learners to articulate causal reasoning, the basis for most models of conceptual change.
- Modeling provides a high level of conceptual engagement, which is a strong predictor of conceptual change (Dole & Sinatra, 1998).
- Modeling results in the construction of cognitive artifacts (mental models) by constructing physical artifacts.

- When students construct models, they own the knowledge. Student ownership is important to meaning making and knowledge construction. When ideas are owned, students are willing to exert more effort, defend their positions, and reason more effectively.
- Modeling supports the development of epistemic beliefs. At the very root of learning are people's beliefs about what knowledge and truth are and how we come to develop these beliefs. From a biological perspective, we accept that humans are marvelously adapted to learning because of the size of their cortex. But what drives people to learn? Sociologists and psychologist talk about fulfilling needs, which supply a solid conative reason for learning. But epistemologically, what motivates our efforts to make sense of the world. According to Wittgenstein, what we know is predicated on the possibility of doubt. We know many things, but we can never be certain that we know it. That uncertainty can only be mollified by efforts to know more about the world. Modeling tools enable learners to externalize and test their epistemological beliefs about the meaning of epistemological constructs, such as knowledge and truth and how those beliefs change over time
- Modeling provides shared workspaces provide a strong reason to collaborate.

Summary

In this chapter, we have argued that mental models provide the best evidence for meaningful learning. Further, we argued that the most effective way to use technologies to foster mental model development is through the use and construction of computational models using model-based software. By modeling domain knowledge, modeling problems being solved, modeling systems, modeling semantic structure, and modeling thinking processes, learners can more readily and more effectively build their internal mental models of the phenomena they are studying. Considerable research is required to explicate which tools and which form of model-based learning (model-using or model-building) is more effective for facilitating mental model development.

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Applying a Critical and Humanizing Framework of Instructional Technologies to Educational Practice

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Abstract Traditionally in the field of instructional design and instructional technology, educators and researchers have focused on technical tools, rather than the socio-cultural implications of technology integration. Thus, integration of technology into educational practice is often made without evaluation of the belief systems informing those choices, and without adequate contemplation of the unique needs of the human users using these systems. Analysis of the ideological perspectives that impact our educational technology, including technological determinism, social determinism, technological utopianism, and technological dystopianism is the starting point of this examination of our relationship with technology. The humanizing framework subsequently outlined draws directly from this discussion of ideology by calling on educators to critique their own beliefs about technology. It serves as the starting point for reflection on the impact of human interaction in educational technology practice. The humanizing framework emphasizes strategies and techniques that promote the integration and development of critical thinking skills, the fostering of student engagement and interaction, and the development of community.

Keywords Humanizing framework/pedagogy · Praxis · Instructional technology · Technological determinism · Social determinism · Technological utopianism · Technological dystopianism · Historicity · "Minds on" learning · Share control · Participatory design · Interaction · Collaboration · Communication · Reductionist theory · Social presence · Learner-centered instruction · Control of learning process

> *Consciously or not, deliberately or inadvertently, societies choose structures for technologies that influence how people are going to work, communicate, travel, consume...over a very long time*
> (Winner, 1980)

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Introduction

Today in education, our technological tools shape and structure the interaction, collaboration, and communication between and among all stakeholders in the educational process: students, educators, instructional designers, and administrators. In our educational policy and practice, we often reduce the term “technologies” to our technological devices because they are “clear and accessible cases of the pattern...of modern technology” (Borgmann, 1984). Often, we fail to reflect on the larger picture of technology practice, beyond just emphasizing the technological devices to examine the whole technical realm of skills, knowledge, devices, and processes. In education, we often interchangeably use “technology” to mean “computer,” forgetting that some of our most effective “technologies” in education are processes and pedagogies that are deeply intertwined with organizational and cultural factors. Even in this chapter, we contextualize the technological in socio-cultural and communication practices, but we will still refer frequently to the impact of technological tools.

While the field of instructional technology traditionally has focused on the technical skills and organizational aspects of technology integration, there is a burgeoning recognition that technological tools possess cultural relevance and congruence (Pacey, 2000) and might be used to empower the individuals and the groups in educational systems by linking the agendas of instructional technology and multicultural education (Damarin, 1998). For effective integration, however, researchers forging those ties need to address the underlying ideologies that fuel research agendas and designs, as well as the design of learning experiences. While there are certainly positive effects of implementing new technologies, these must be balanced against the reported adverse effects. To put the discussion of causes and values of technological change into a larger frame, the first section of this chapter will address commonly encountered ideological orientations toward technologies.

In addition, with much of the focus of educational technology aimed at our technological devices, and less delving into the organizational, pedagogical, and cultural implications of new technological tools, it is easy to lose sight of the humans who will be impacted by their use. Yet the cultural aspect of our implementation of educational technologies has the most impact on the individual experience of engaging in learning via multimedia, virtual learning spaces, or distributed communities. Just as mastering a culture depends on fluency with its language system, navigating technological tools and systems must be mastered if one wishes to realize agency and autonomy in the information society (Taylor, 2007).

For example, as we integrate computer-mediated learning spaces into education; such as, discussion boards, online chats, or virtual worlds, we are shaping an experience of a specific way of being and interacting with others. The communication is inherently different from a face-to-face interaction (Spagnolli, Varotto, & Mantovani, 2003; Watts, Nugroho, & Lea, 2003), and there are not well-developed role models or prior experience for use of communication of this type in educational contexts. As educators struggle to orient students to "being" humans while using new communications technologies, we have a responsibility to critically consider a humanizing framework as we implement new media and technologies to the learning process. Therefore, after the examination of ideologies, we present characteristics of a humanizing framework of instructional technology integration to suggest guidelines for consideration by all educators adding technology to their instructional practice.

Ideologies of Technology

Before approaching technology integration in instruction, it is imperative to examine one's own assumptions and beliefs about technologies and their impact on human users. Because ideologies are all-encompassing in our thoughts and interactions with others, they are hard to detect and especially hard to question (Smart, 1958), as we have to step outside of this particular frame of thought that surrounds us to examine how our way of thinking influences our actions. This examination can also be useful in analyzing the language used in policy and in research to better understand our motivations in technology integration in education.

Our views on what technologies are and what role they play in education are a prominent example of ideology, although we simultaneously deal with a multitude of conflicting ideologies. For example, technologies are seen as drivers of change in education either by contributing to positive social change, increasing cognitive skills, or developing skills that are necessary for the workplace. For example, in some of the literature, multicultural educators, enamored with technological utopianism, see technology as a way to level social inequities (Marshall & McCarthy, 2002). At the same time, there is a near equal amount of literature that deals with the broken or unfulfilled promises of technology, for example, the challenges presented by access to devices and understanding of how to use various technologies effectively vis-a-vis literature on the "digital divide" (Attewell, 2001; Cullen, 2003; DiMaggio, Hargittai, Neuman, & Robinson, 2001; Norris, 2001; Servon, 2002; Servon & Nelson, 2001).

In the following sections, we will examine the following ideologies: technological determinism/social determinism, and technological dystopianism/utopianism. As we will show at the end of this section, these ideologies are reductionist and obstruct a complex view of the issue at hand.

Technological Determinism/Social Determinism

Technological determinism involves seeing technology as the fundamental force of social change, and technological development and progress as moving according to its own internal logic (see Mody, 2004 for applications in the field of nanoscience). From a viewpoint of technological determinism, humans have little agency in a world run by technologies (Smith & Marx, 1994). A prominent example is the expression: "the computer is changing world society at all levels" (Evans, 1979 cited in Robins & Webster, 1989, p. 24), where the technological tool is the entity with agency to effect change. Commonly heard expressions like "technology is coming your way" and "I have a tool that's going to fix that problem" are encountered by people working with technologies on a daily basis. These sentiments assume a separation of the technical from the social and isolated and independent effects of technology (Grint & Woolgar, 1997; Ovortrup, 1984). In education, technological determinism can manifest as the idea that students and educators have to "keep up" with the technologies or be "left behind," as if the technologies are driving changes and decisions in the instructional process.

One can classify technological determinism into two forms, hard and soft (for the distinction, see McGinn, 1991). Proponents of hard technological determinism take an extreme viewpoint that technologies are dominant, irreversible, and *cause* social change, where proponents of the soft form identify technology as one influence among others, and not an absolute determinant of social change.

Social determinism is a converse perspective to technological determinism, where technology is an incidental part of social change. If technological tools are in the focus at all, then what matters is not the technologies themselves, but the larger processes, the social, political, cultural, and economic systems in which those technologies are embedded (MacKenzie & Wajcman, 1985). Where technological determinism identifies autonomy as an attribute of technological innovation, and society has "to catch up" with the next technological innovation; in social determinism, society and individual players within are seen as autonomous and thus humans drive the development of technology to serve the need and goals of society.

Technological Utopianism/Dystopianism

Where technological and social determinism are attempts to answer the question of what causes change, technological utopianism/dystopianism are attempts to value the resulting effect of the change, regardless of its cause.

Technological utopianism embraces the promise of technology (see Segal, 1985 for an overview) and portrays computing technologies as "enabling" a utopian vision of society. Some authors "enchant" or "proselytize" us with images of new computer technologies that offer never-before-experienced possibilities of manipulating large amounts of information with little effort – to create insights, to search for information, and to facilitate collaboration and social engagement between people. Utopianists sketch a future emphasizing the egalitarian and democratic power of technologies to provide equal access to information coupled with the positive effect of technologies on efficiency and productivity, resulting in a liberating effect whereby people have more free time for creative and leisure endeavors (Mainzer, 2005). From a consumption point of view technological utopianism emphasizes societal benefits to technological tool use (West, 1996). This philosophy embraces a vision of the technological revolution creating a new civilization in which old problems are overcome. A technological utopianist viewpoint is alluring because it is a simple solution, a technological fix, a tool that will free us from the social problems we have created, in contrast with the far more complex process of engineering social change through human processes (Weinberg, 2003).

It should sound very familiar once one starts to evaluate the advertising world and the purported premise of technological "progress." Essentially, technological innovations are often touted as liberating us from the grime and sweat of labor (e.g., washing machine, dishwasher, gasoline-powered lawnmower) and provide a life of leisure (e.g., television). Borgmann (1984), in his chapter "The Promise of Technology," cites three advertisements from the early 1980s promising technological fixes: an electronic gadget that translates foreign languages, gourmet food at home "without waiting or cooking," and a jogging computer that will result in "greater endurance" and less tiredness (1984). Here, the onus of education, food, and health are placed on the technological devices, rather than on the human effort, talent, or ability.

Technological dystopianism is the philosophical counterpoint to utopianism. In a dystopian view, technologies have gained control of human existence and changed conditions for the worse. In other words, this is a vision of a technology-created hell. For example, Postman's work *Technopoly* describes technological society as one where all features of culture: religion, art, privacy, and truth are overrun and redefined by technology (1993). A dystopianist would argue that any form of technology adoption, such as the recent proliferation of computing, will amplify existing societal flaws, creating a society where people will lose their freedom to corporations and government agencies (as organizational technologies) or become dependent on complex technological tools that they don't understand. According to this way of thinking, technologies have precipitated and will continue to cause a greater division between the rich and poor (Powell, 2002; Schement, 2002). More people will be out of work, and human beings will be reduced to robotic devices, unable to function without their computers. Remedies to acute problems created by these technologies will introduce new chronic problems, and human alienation will flourish as people will interact with technologies more than with other human beings.

Conclusion for Ideologies

Any form of these technological ideologies – on the determinism or the utopian/dystopian spectrum – is reductionist. A reductionist theory reduces some class of phenomena to some simpler phenomena of another class (Gellner, 1974). In the case of technological and social determinism, complex intertwined relationships between technology and society are either reduced to exclusively societal or technological forces. It is too simplistic to simply argue that there are no positive or negative effects of technology. To indicate that either technology or society are exclusively and independently causal drivers for change or to possess the expectation of solely positive or negative effects as a result of technology are assumptions that need to be critically examined and answered depending on the respective context.

Similarly, utopianism and dystopianism are extreme positions at the opposite side of a spectrum that contains many more moderate positions. Both dimensions of technological/social determinism and dystopianism/utopianism can be contrasted with a holistic or systemic view (v. Bertalanffy, 1968), in which the whole cannot be explained by a linear causality model or by analyzing only identifiable single components of the system. In this chapter, we can only address these issues rudimentarily. (For a broader overview of this discussion, see Tech Trends Special Issue on Systemic Change edited by Reigeluth, 2006,Vol. 1.)

A Humanizing Framework

Rationale for a Humanizing Framework

The combination of technological determinism and technological utopianism fuel the rationale for spending billions of dollars to equip schools with technological tools despite mixed reviews that such expenditure results in increased learning proportional to dollars expended (Clark, 1983; Ross & Lowther, 2003; Schacter, 1999; Wenglinsky, 1998). Educational leaders need to ask the questions of how these innovations will holistically impact the learning experience, rather than buying into deterministic or utopianist arguments for technology integration. Furthermore, educators need to evaluate the allocation of resources to ensure that technology tool integration occurs for beneficial and culturally appropriate purposes. At the same time, we cannot pretend that technology tools are inconsequential or unworthy of larger discussion because our use of them is inextricably intertwined with social and cultural realities (Mesthene, 2003). Thus through critique and analysis of the impact of technological tools on the experience of each learner, educators reduce the risk of falling prey to the fallacies of determinism and utopianism at the expense of the humans participating in the educational process.

Though individual empowerment has not necessarily always been the historical goal of education, for many educators the notion of impacting individual lives is a strong motivator for being an educator. Society's rapid adoption of new technologies has had complex implications, particularly on individual's perceptions of their agency to effect change in their own life and in their community. Assuming that technical mastery of new technologies equals empowerment amounts to reductionist thinking that will not necessarily benefit learners. Empowering students requires guiding them in developing critical thinking and analytical skills (Davis, 2003). Thus, the emphasis throughout this framework focuses on the development of critical thinking and independent thinking, including but not limited to, "the use of logic, the critical spirit, dialogical reasoning, assessment of criteria, the relationship of content, caring and connections with criticism" (Hemming, 2000).

The following humanizing framework of instructional technology is derived from the literature of philosophy of technology, instructional design, learning theory, communication theory, multicultural education, and sociology. The wide scope of the inquiry is intended to combine the many disciplines that have called for attention to the humanity in the pursuit of education.

Question Technology

Foremost in a humanizing framework of instructional technologies is a grounding of practice in a critical questioning the relationship between the educational context and technological tools. This notion of critical questioning comes at a time when critical thinking and higher-order thinking skills are at the forefront of the educational agenda. The ISTE NETS*S/T standards call for high school students to be able to: "Analyze advantages and disadvantages of widespread use and reliance on technology in the workplace and in society as a whole" and to "identify" capabilities and limitations of contemporary and emerging technology resources" ("ISTE National Educational Technology Standards (NETS)," 2004). It is impossible to achieve these standards without an emphasis on questioning, yet at the same time, ideological beliefs about the positive uses of new technological tools are so ingrained that often educators themselves cannot objectively analyze the disadvantages of technological tools in order to begin the questioning. Recent research analyzing stories of how teachers integrate technology into their classrooms corroborates that the most neglected parts of the NETS*S standards are those aimed at a critical evaluation of the role of technology on society and on ethics of work with computers like critically evaluating the information found on web sites (Niederhauser, Lindstrom, & Strobel, 2007).

Often, humans see technological tools in an instrumental, transactional way, in other words, purely in terms of how they can benefit us, a by-product of life in Habermas' public sphere (1984). It is imperative that educators or designers of learning experiences constantly question and challenge technology use and take extra steps to ensure that relationships with learners move beyond a transactional and instrumental view of students purely as recipients of knowledge. Thus, we can see that just in the questioning of technology integration and how it impacts group interaction, we are brought into the question of how educators relate to and interact with students.

Questioning technology does not mean rescinding the use of technology tools, but does require a critical reflection on its effect on interpersonal communication. Critical reflection on technology use need not be equated with a "luddite" or "laggard" (Rogers, 1995) attitude toward technologies, but the pejorative connotation of these terms referring to those who choose not to adopt new technologies reveals our cultural bias toward those who voice discomfort with or resist adopting new technologies (Davis, 2003). If we fail to recognize and question the ways in which we let technology shape all aspects of culture in terms of language and its forms; interactions with friends, family, colleagues, and strangers; and use of recreational time, we are not only failing to question technology, but we are also blind to its sway over our lives.

Abandon the Fiction of the "Technological Fix"

Just as Bartolome (1994) demanded that educators stop looking for a pedagogical fix in the language classroom, educational technologists and administrators need to stop seeking the "technological fix" in the technology-enhanced classroom. Bartolome's work responded to teachers who had asked her for *the* one best method to teach students language. Her response was to propose a "humanizing pedagogy" that commences with incorporating and valuing students' histories and unique experiences and where the educator uses a variety of methods to reach students across a range of learning styles, including cooperative learning, process writing, reciprocal teaching (Bartolome, 1994). In addition to those pedagogical strategies, we would add approaches that encourage students to think independently, in other words developing abilities to synthesize, analyze, and evaluate per Bloom's taxonomy (1984), including but not limited to experiential learning, problem-based learning with the use of ill-structured real-world problems, simulation (Chung, Harmon, & Baker, 2001), and collaborative group projects.

From a purely "technical" viewpoint of technology, there is much allure to the idea of a "technological fix," and the preceding discussion of technological utopianism points to why educators seek this miracle cure. This holy grail is what has, in fact, fueled many of the early educational technology studies and instilled distrust in many educators who feared that computers and the like were being developed to replace them in practice (Clare, 2002; Zophy, 1998). Weinberg in his piece, "Can Technology Replace Social Engineering?" argues that "technological fixes" are much easier than trying to engineer mass social change. However, his examples of mass production as a solution to poverty (now there's enough "stuff" for everyone) and the H-bomb as a solution to war (higher stakes for engaging in one) are at best, simplistic. In contrast, Pacey (2000) warns that a technical fix without "social and cultural measures" will be unsuccessful, and Mesthene offers the balanced view that, "technology is continually creating new possibilities for social action as well as new problems that have to be dealt with"

(Mesthene, 2003). Therefore, another look at Weinberg's examples reveals more complexity than he suggests. With the advent of mass production, which at least increased a material standard for living for many people in the world, we now have to deal with overcrowded landfills, increased pollution, and exploited human labor in less "advantaged" parts of the world. Though the H-bomb may, as Weinberg states, stifle war, it has not achieved peace. Without involving the human players in the equation needed to barter peace, the technical "fix" is inherently useless (Pacey, 2000).

From this discussion of much larger social issues, we can understand that any technological shift will create both remedies and additional problems. This applies to the integration of technologies in education as well. While implementing any new pedagogical strategies combined with new technological tools, the instructional aim of the task should be foremost, with the technology used to support the educational objective. There is no one technology that will facilitate easier transfer of knowledge for *all* students, or make difficult concepts clear for *all* students. Furthermore, each technological tool brings with it cultural implications about expectations for learners interacting with that tool (see McLoughlin, 1999, p. 233 for a detailed analysis of socio-technical implications and resulting cultural expectations). Instead of seeking one method or tool to reach all students, we need to offer a variety of technology and methods to be used in ways that help students excel. At the same time we need to be cognizant that when we ask students of any age to use new technologies and processes, we are opening a Pandora's box of both opportunities and potential clashes with existing cultural identities, particularly where technology is being implemented to "bridge" opportunities for the disadvantaged.

Integration of Theory into Practice for Educators and Students

Praxis, the application of theoretical knowledge and critical reflection to practice, is an essential aspect of professional practice because it requires the grounding of one's practice in a body of external knowledge, existing theory, and highly contextual situations, thus linking one's knowledge and practice to a human community. Praxis is as an unending cycle of action, reflection on action and modification of action, corresponding with this reflection. As mentioned in the rationale for this framework, there is a need for humans to recognize their own agency, and "theorizing in terms of…praxis…requires a broad view of human agency, emphasizing the integration in practice of agent, world, and activity" (Lave & Wenger, 1991). In other words, one has to believe in one's own agency to effect change through action driven by critical reflection and through participation in a community of practice.

Beginning with the aforementioned critical reflection on the ideological influence on technology integration, praxis, as the integration of theory and practice, is an essential tool for those in instructional technology. Educators and instructional designers might consider theoretical perspectives about the organizational and cultural impact of new technologies on social relationships and examine the proposed learning outcomes and objectives, which often focus on marketable skill orientation instead of the development of more complex and lasting reading, writing, and critical analysis skills. Finally, based on reflective reading, educators might consider the effectiveness of technological solutions and approaches in course design and delivery, given the larger picture of what learners need from the educational process.

Praxis is not just for educators. By providing students with opportunities to integrate the skills and knowledge developed in authentic contexts and asking students to reflect on these experiences, educators can provide students with tools useful in lifelong learning. Educators need to be the guide for students in critically reflecting on the texts used in their classes and their experiences. bell hooks writes, "Students have often learned. . .that college is not the "real" world and that book learning. . .has no relevance. . .outside university walls" (2003). In a time where the development of literacy skills competes with the allure of being passively entertained by television and multimedia, students need to be tasked with identifying the value of the information found in books. Further, these experiences will ideally be linked to authentic "real-world" scenarios, interaction with a "real-world" audience, or discussion of "real-world" events – and all of these can be facilitated by carefully choosing new technologies that will link students to people and ideas and enable them to participate in challenging and rewarding tasks. By encouraging students to make connections between what they read and what they do, and to develop their own reflective praxis, we can empower students to think critically about their actions and agency in the world.

Examine Activity System and its Historicity

In order to contextualize educational technology integration in the social and cultural, we need to examine the activity system surrounding technology use, and the inherent historicity involved as we engage in technology practice. Important in analysis of the activity system is an understanding of mediating artifacts, who the members of the activity community are, their roles, and rules of the community, as well as proposed goals and actual outcomes. As Engeström has described in his work on conceptualizations and application of activity theory, "activity systems" have historicity (1999; 2001), meaning they "take shape and become transformed over lengthy periods of time" (1999, pp. 136–37). Borrowing from Heidegger's philosophy (1962), historicity refers to the intersection of purpose and progression with the construct of time. Historicity is important in this framework because it grounds educational technology adoption within the larger picture of previous innovations and their ensuing impact. The implication is that educators cannot presume that learners enter an educational setting without prior experience and cultural association with the tools and processes they will encounter. When new forms of interaction such as a specific model of team-work or new computer technologies such as discussion boards are introduced, learners will most likely have had some experience with these and developed preferences on collaborative forms of learning or respectively, on different forms of computer-mediated communication.

The historical aspect is not a uni-dimensional time-line that we all share, but includes several dimensions: (a) the history of the theoretical ideas and tools that shaped the activity (system); (b) the activity system including the students and the instructors bring their own history, as Freire asserts: "through their continuing praxis, men and women simultaneously create history and become historical beings" (1999); (c) the activities and objects present in the local context have a history; and (d) the interaction between the different layers of historicity, which not only is different from the histories of individuals in a community or the community or the objects, but also includes the tensions and contradictions that naturally occur between these different layers (Engeström, 1999).

By embedding our inquiry in a systemic framework and an exploration of both successful and unsuccessful past practices, educators can examine how current implementation of new technologies mirrors these longitudinal patterns. Activity theory combined with praxis can provide educators with a helpful approach that examines artifacts, community, roles, and goals, and offers a framework in which educators can act to effect change based on reflection on these patterns and theoretical knowledge.

Design "Minds On" Learning

Technological tools are often integrated into educational settings on the basis that because learners see it as "fun," it will motivate them to learn (Garrison & Bromley, 2004, p. 601). As multimedia has become more sophisticated and commonplace in the form of "edutainment" (Buckingham & Scanlon, 2004; Okan, 2003; Perrone, Clark, & Repenning, 1996), learners might expect to be "entertained" by their teachers (Conlon, 2000). Integrating new technology tools solely for the purpose of entertaining is disservice to all stakeholders in the classroom. Instead, educators should think in terms of student engagement and involving students into the learning process in a "minds on" approach, requiring critical thinking, problem-solving, content creation, and collaborative project development.

Thus instead of competing with edutainment, technology tools should be leveraged to increase student engagement with the content area and with fellow learners. To engage learners with the content requires authentic activities, which might vary from carefully scaffolded (or well-structured) case studies (Riedel, Fitzgerald, & Leven, 2003) to ill-structured problem scenarios (Chen & Ge, 2006; Jonassen, 2000, 2004). These approaches require learners to develop critical thinking and analytical skills (Chambers, Angus, & Carter-Wells, 2000; Frederiksen, 1984).

In terms of engaging with fellow learners, the social context for learning (Vygotsky, 1978) is a well-established, essential component in learning. “Higher mental functions are, by definition, culturally mediated; they involve not a ’direct’ action on the world. . .in so far as that matter has itself been shaped by prior human practice (e.g., it is an artifact), current action benefits from the mental work that produced the particular form of that matter” (Cole & Wertsch, 1996). These authentic activities should be designed to require learners to engage with each other, such as through structured peer interactions (Ge & Land, 2003) and through active questioning and discussion (Picciano, 2002).

Using Tools to Build Community

Learning involves an enculturation process and an apprenticeship into content-specific discourse, which is always embedded in a social context. From cognitive learning theory, we understand that learning is situated and contextual and that learners experience the social dimension of purposeful communities both through direct involvement and through legitimate peripheral participation (Lave & Wenger, 1991). For this reason, educators should expand their activities from designing content environments to include the design of social spaces, created to scaffold and favorably impact the human interaction in the instruction and create a venue for different forms of participation. Within this framework, “social presence” (Garrison, Anderson, & Archer, 1999; Gunawardena, 1995) should be an essential aspect of learning design, particularly in distributed learning environments.

Building community is a challenge especially when implementing new communication technologies because each medium requires different rules of discourse and interaction. A meta-analysis of research on text-based computer conferencing revealed that groups function differently when online and asynchronous, for example,taking longer to reach consensus (Bordia, 1997). Furthermore, group members not only interacted differently, with less incidence of members caving into social pressure, but also reduced interpersonal understanding (Bordia, 1997). Cultural differences in interpersonal communication can lead to further difficulty when moving to text-based computer-mediated communication, as the impact of the removal of social context cues can impede effective communication and cause misunderstanding (Leh, 2001; Tu, 2001). While challenges of text-based computer-mediated communication have been identified, further research in computer-mediated communication in video chat, virtual worlds, and other domains is needed to identify specific challenges for communication in those modes.

The focus of integrating technology in education should also concentrate on bringing people from different perspectives together: “All too often we think of community in terms of being with folks like ourselves: the same class, the same race, same ethnicity, same social standing” (hooks, 2003). An oft-cited “advantage” of Internet technology is access to a global community for classroom inquiry (Belz, 2005; Solem et al., 2003; Songer, 1996). However, having the means to connect globally is useless without the human connections and interpersonal networking that make those interactions possible. The more computer-mediated communication is used to build these social relationships, the competent educators and learners will have to be about effective intercultural computer-mediated communication.

While it is easy to set forth that community needs to be built, building a community requires scaffolding of communication, development of trust, finding and supporting shared goals, examination of shared histories, and fostering of respect for the various stakeholders in the community.

To scaffold the communication, rules of discourse should ideally be set forth from the first community meeting. Engeström's activity theory sets forth "rules" as one of the key components guiding interactions between participants in an activity (1999). Rules of discourse should ideally be discussed openly by all members of the community, and supplemented by expectations of the instructor/educator. In the case of a distance education setting, where most, if not all, communication is decontextualized from face-to-face contact, examples and scaffolding of how to communicate in a distance forum, such as rules of "Netiquette" should be discussed openly. As media innovations have shaped our perceptions of appropriate style and usage (see Baron, 2002 for an historical overview of the influence of media over linguistic style), reflection on how e-mail, messaging, blogging, micro-blogging, and yet-to-be-named communication forms affect message interpretation is an essential part of classroom orientation. Assigning a key facilitator for each assigned communication, ideally a student, to synthesize ideas is helpful in both to facilitate communication and develop student leadership.

As for building trust, there is no exact recipe, but promoting transparent "rules of discourse" can assist students in reflecting on their manner of communication in ways that are appropriate for the community. A research study of building trust in online learning communities identifies "swift trust" as a phenomenon of decontextualized interaction (Meyerson, Weick, & Kramer, 1996), and characterized instructor–student communication as an important facet of the development of "swift trust," particularly in what manner and how quickly the instructor introduces and models acceptable communication and conveys social emotional language and enthusiasm in their written statements (Coppola, 2004).

Finally, all participants in a community bring prior experience and "histories" that inform their construction of knowledge in the course content, and guide their interactions with their professor and peers. Ladson-Billings's (1995) analysis of "culturally relevant pedagogy" identifies speech and language practices as imperative in developing a shared understanding, and in her research with classroom teachers identified "reciprocal dialogue" as an essential research tool to ensure that the "teachers' histories and interests determined how much time was spent on various areas." Likewise in a classroom setting, it would seem appropriate also to develop a dialogue with students to ensure that their histories and interests are represented in the direction of class materials and discussions. This needs to include valuing the experiences that have helped shape each student's beliefs and attitudes that will impact his/her interaction with the rest of the classroom community.

Share Control

Integration of computing technology in schools has not necessarily radically impacted other existing educational technologies, namely pedagogy. While technology integration is sometimes used as an excuse to redistribute classroom control to users, the best reason to share control with learners is to scaffold learners' intellectual development to develop autonomy and ownership of their learning process.

Studies that investigate how computers are being used in the classroom report students in less affluent schools experiencing computers as drill and kill, skills-based exercises, or step-by-step instructions of use (Garrison & Bromley, 2004; Warshauer, 2000; Wenglinsky, 1998). In contrast, learner-centered instruction necessitates that any use of computers should be to achieve an end and "learn while doing" not to learn a software program in and of itself (Soloway et al., 1996). Besides providing a context of potential empowerment of learners, learner-centered instruction requires the learner to make decisions, problem-solve, and construct their own understanding of a given problem or task (McLoughlin & Luca, 2002).

Research indicates that there may be significant cultural barriers within a school to implementing learner-centered instruction regardless of the presence of computing technology. Garrison and Bromley's recent study at one educational site (2004) identified both student and teacher activities that contributed to a culture where teachers were unwilling to give up control. The identified contributing student activities were "pretending," which entailed feigning inability to do tasks the student was capable of and "undermining," which entailed sabotaging technology; for example, kicking the power strip to turn off a computer that was in use. As a result of these student activities, the researchers identified the teachers as engaging in what they termed "defensive teaching," which entailed giving students step-by-step instructions that minimized potential discipline issues.

Thus, it is not enough to say that teachers need to give up control of the learning process and students need to take control. Educators need to be strong facilitators, coaches, and guides. There are cultural and historical precedents, and encouraging individuals to think outside of traditional roles is challenging. Educators and learners need models of effective learner-centered instruction and administrative and institutional support to be successful. However, where technology is being integrated without consideration of the social and cultural aspects of the teaching process, there is a real danger of failure to engage and assist learners in the development of critical thinking skills.

Participatory Design: Using "Learners as Designers"

Participatory design, a design and development approach in software development, can provide us with practice models in integration of technologies in this humanizing framework. As Bettina Törpel (2005) points out, "participatory design of computer applications is about the direct participation of those who will be affected by the development of a particular computer application in the decision-making, design and/or development process" (p. 177).

Thus, a helpful strategy in redistributing instructional control might be implementing a "learners as designers" design strategy. Rooted in a constructivist paradigm and the notion of computers as "mindtools," computers are perceived and utilized as partners for the intellectual and social endeavors of the learners (Jonassen & Reeves, 1996; Jonassen, 2006). This re-defined relationship between learners and computers highlights the notion of "designers as learners" and "learners as designers." As Jonassen, Wilson, Wang, and Grabinger, (1993) report, instructional designers learned far more by designing computer-assisted instruction than the target audience would probably ever learn from the designed end product. The rich teach-back literature (Johnson & Johnson, 1987) and studies on cohort teacher training (Forsyth & Schaverien, 2004) show learners are especially successful at mastering target objectives when designing and teaching for their peers. Thus, asking learners to engage in the design and implementation of learning activities could be a powerful model for engaging learners.

In the realm of more packaged learning tools, such as content management systems or computer-assisted systems, there are not many attempts to engage students in the design of technologies. Students are asked to perform usability testing or asked for input in interface design issues (Tselios, Avouris, Dimitracopoulou, & Daskalaki, 2001), but the functionalities of the technology and the activities that it supports, are prescribed by theoretically based design models, empirical research, or ideas of the instructors or designers. As highly valuable and necessary such input is, input of students as the users of the model is often not sought and therefore not integrated. This might be an area to consider involving learners as potential end-users, who will be directly impacted by design decisions.

Conclusion

Examining ideological perspective in relationship to technology is an imperative for all educators, instructional designers, administrators, and learners. Without this introspective analysis of the beliefs informing educational technology integration, the core essence of this humanizing framework of educational technology is lost. The importance of developing a humanizing framework of instructional technology is in that it empowers each educator to critically evaluate his or her own beliefs about technology and to engage in a critical dialogue with other educators and learners about these beliefs. The core principles of the framework are grounded in educational literature: fostering of independent thinking skills, infusion of authentic and problem-based learning tasks into instruction, implementation of learner-centered instruction, and engagement of students in interaction. Furthermore, this framework takes into account larger socio-cultural issues, historical uses of technology, and patterns of community use of technology that are too often ignored in the instructional technology literature. From this perspective of this humanizing framework, the human learners and the larger educational goals become the focus of any technology integration, and the technological tools remain in the background of human decisions about their appropriate tool use for achieving community goals.

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When a Peer Group Isn't Needed: Effective Online Learning in an Individual Mentoring Model

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Abstract In this chapter, we discuss the design and refinement of the Learning to Teach with Technology Studio, an online professional development environment for teachers who are interested in learning how to use technology to support inquiry-based approaches to teaching and learning. We specifically focus on our initial design commitments of flexibility and relevancy and how they were embodied in the system. We examine the iterations made to the system in response to our design-based research efforts and explore the implications of our research on our beliefs about the role of collaboration in learning in online environments.

Keywords Collaboration · Peer-groups/interaction · Group work · Online professional development · Inquiry-based approaches · Online learning · Mentoring · Online collaboration · Technology integration · Curriculum content standards · Guided problem solving · Learner-centered teaching · Technology access · Self-paced learning · Feedback · Mentoring · Discussion forums

Introduction

Learning to Teach with Technology Studio (LTTS) is a suite of online professional development courses grounded in an inquiry-based learning model (Duffy et al., 2006). Teachers complete the courses individually and at their own pace with the assistance of a mentor provided by LTTS. This is done in order to enable teachers to research and examine specific teaching tools and techniques (such as Webquests and Geometer Sketchpad) in ways that are most relevant to their individual classrooms. Each course is designed around a central inquiry question, which is focused on a teaching problem (e.g., how to support students in seeing connections between school mathematics and the real world). The courses engage teachers in investigating specific issues related

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to the teaching problem as well as designing a product (a lesson plan or teaching unit) that they can use in their own classroom as a response to the course's driving question. The courses have been extremely well received by teachers as indicated by high levels of completion, positive evaluations of satisfaction and perceived learning, and reports of useful impact on classroom practice (Duffy et al., 2006; del Valle & Duffy, 2007, Osman & Duffy, 2006).

Despite the overwhelmingly positive response by our target audience, we have been questioned by our colleagues about the lack of collaboration and peer interaction in the system (for example, they have asked us whether this is the type of system we want to promote with teachers). While we understand and share these concerns, during the past 9 years of research and development on LTTS we have made multiple attempts to introduce peer interaction into the system, only to find them rebuffed or ignored by the teachers. It appears that we have been unable to break through the closed-door culture that permeates the teaching profession to support teachers in engaging with each other, or even valuing this kind of engagement.

In this chapter, we explore the design issues and tradeoffs we faced in relation to online collaboration between teachers in the context of LTTS, and the refinements to our understanding of our design principles that resulted. Our work is grounded in a design-based research approach in which design is driven by theory, and research on the design seeks to refine that theory (Brown, 1992; Design Based Research Collaborative, 2003). We begin by presenting the LTTS system in its current form and then summarize the results of its evaluation. We then walk through the lifecycle of design that brought us to this point: our initial design commitments and their instantiation, modifications made in response to a pilot test, and our multiple attempts to introduce peer interaction. We conclude by discussing the broader implications for thinking about collaboration between teachers and online collaboration in general.

The Current LTTS System

LTTS (http://ltts.indiana.edu) has a catalogue of approximately 60 online inquiry-based courses for teacher professional development addressing a variety of content and skill areas. Each course aims to support teachers in designing inquiry-based lessons, integrating technology as a tool for student inquiry, and meeting curriculum content standards. All courses are designed to be self-paced and can be completed by teachers individually. This allows teachers to select a professional development opportunity that focuses on something they regard as relevant to their current teaching needs. Since LTTS courses are not semester- or cohort-based, teachers can start a course at their convenience. They are then given 12 weeks to complete the anticipated 30 hours of work required by the course[1], and have the freedom to engage in course activities at whatever time

[1] We note that many teachers report spending much longer than this on their coursework.

and pace works for their schedule. The only imposed structure is the overall 12-week time frame for completing the course.

The course architecture was designed based on a guided problem-solving approach in which the teachers begin with a curriculum problem and, by working through a series of tasks, creates a lesson plan tailored for their classroom. The resulting lesson plan should be learner-centered (McCombs & Whisler, 1997), pedagogically sound, and address relevant curriculum standards. For example, one course begins with the problem of making mathematics learning meaningful for students by showing connections to other subject areas and to the real world. The proposed strategy for the course is to develop a hands-on unit for students to research stock market performance and learn how to use spreadsheets to make financial decisions related to the stocks. A teacher completing this course would develop a unit plan for his or her particular classroom that engages students in a relevant simulation of the experience of investing in the stock market in order to understand how mathematics is applied in the real world.

To facilitate the process of moving from problem to solution, teachers work through four to seven tasks that serve as proximal goals and encourage them to address specific parts of the inquiry question in order to develop their final product. They do this by moving through cycles of asking questions, researching issues, making decisions about their own lesson plan design, reflecting, and revising. For each task, online course materials provide a description of the task and what must be submitted, guidance for how to approach the task, and links to learning resources (primarily other external web sites that are relevant to the task). The deliverable for each task serves as part of the final product the teacher will submit upon completion of the course; hence, there is a building process. Each task also requires the teacher to provide a rationale for the design decisions they make as they develop that part of their lesson plan. The final course product is an overall lesson plan that addresses the core question guiding their inquiry (e.g., How can I help my students use technology to research and analyze financial information?). Teachers also complete a self-reflection on the process and product of their course and provide a rationale for their lesson plan design in terms of how well it addresses inquiry-based theory, specific curriculum standards, and learning concepts/principles specific to the course (e.g., principles for using spreadsheets to track stock market trends).

Teachers are supported in their work by an LTTS mentor, who is an experienced teacher on the LTTS team. This person welcomes them to the course and provides guidance and interaction around the deliverables for each activity in the course. The mentor provides feedback on each submission and asks probing questions that push the teacher to think deeply about issues he or she may not have considered. The mentor may also ask for clarification or elaboration, provide suggestions to enhance the lesson plan, or suggest particular resources that may be of use to the teacher. Mentors may also provide encouragement and reminders of deadlines as needed. We assert that the mentoring is a vital aspect of the course experience for teachers given that approximately 50% of the submissions from teachers are revised after mentor feedback is provided. Interestingly, these revisions most often occur at the teacher's discretion and not because they were required by the mentor. As with each of the intermediate tasks, the mentor provides feedback on the final lesson plan and the teacher has the opportunity to make further revisions. Upon completion of the course, the mentor provides the teacher with a certificate of completion.

Overall Evaluation and Impact of LTTS Courses

Elsewhere (Duffy et al., 2006), we have reported the details of an evaluation study conducted based on 107 enrollments in the LTTS system as it currently exists. Overall the results were extremely positive based on self-report data as well as the quality of the teachers' work. Eighty-four percent of the participating teachers completed their course(s). This compares favorably to typical online completion rates of 40–70% (Hezel Associates, 2003). Satisfaction levels among teachers who completed their LTTS course(s) were also high. Using a Likert-scale instrument, 87.8% of teachers either *agreed* or *strongly agreed* that that they "learned a lot" in their course. This was true regardless of their past experiences with technology or learner-centered teaching. In addition, 90% of these teachers said that they expected to use the lesson plan they produced in the course in their own classroom. When combined, these data indicate that teachers found the LTTS courses valuable and relevant to their classroom practice.

As Bitan-Friedlander, Dreyfus, and Milgrom (2004) have pointed out, beyond providing an experience that leads to teacher *learning*, the ultimate goal of professional development is to change teacher *practice*. To investigate whether LTTS courses were actually impacting classrooms, we conducted a follow-up survey with a subset of 20 teachers who completed an LTTS course 6–18 months prior. Of the respondents, half reported that they had already implemented the lesson they developed in LTTS and two more indicated that they planned on teaching the lesson as soon as they got to that part of the curriculum. All ten teachers who implemented their lesson indicated that their implementations went well and several specifically mentioned noticing high levels of student engagement. The only problems cited were related to the time-consuming nature of the lessons.

We also asked this group of teachers if their experience in LTTS had impacted their teaching practice more generally. Fifteen of the twenty teachers indicated that it had. Specifically, eight teachers reported that they tended to apply more inquiry-based teaching strategies, five said that they were more learner-centered in their teaching, five said that they felt more ready to integrate technology into their lessons, and three said that taking an LTTS course had impacted how they planned other lessons for their classroom. Several teachers gave specific examples of how their classroom practice had changed. For example one respondent said, "the [LTTS] lessons made me look at the whole curriculum, and encouraged me to implement algebra in a way that does not intimidate students." Another teacher commented, "the LTTS experience has impacted how I do my lesson plans. I'm more aware of my students and their needs." While we acknowledge the limitations of self-report data in providing definitive evidence of changes in the teachers' *actual* practice, the fact that teachers generated such specific responses to an open-ended question suggests that they were impacted in some way that affected how they thought about teaching and learning. Additionally, in another study of 59 LTTS participants (del Valle & Duffy 2007), the self-reported ability to transfer learning from LTTS to other classroom situations was assessed through three items with an internal consistency (Chronbach's alpha) of 0.90. All of the teachers rated their expectation for transferring their new knowledge to their classrooms very high with an average of 4.67 on a 5-point Likert scale.

In summary, this recent evaluation study indicated that LTTS was successful at engaging teachers in creating a product that they perceived as relevant for their classroom practice. These findings are consistent with the various professional development standards that encourage the use of personally meaningful activities as well as teacher participation to achieve high-quality professional development (e.g., Elmore, 2002; Hill, 2004). LTTS provides a model for professional development that appears to be successful at meeting the teachers' personal needs and, possibly, impacting their classroom practice to be more consistent with learner-centered approaches.

In this section, we have described the final LTTS system and provided an overview of the data that indicate its success as a professional development system. In the remainder of this chapter, we outline our underlying design commitments and provide details about the research we undertook to better understand aspects of those commitments and the changes the research made to our understanding of learning in this kind of environment. In particular, we will focus on the role of interaction and collaboration in LTTS. Regarding the latter, we have long advocated the importance of collaboration in the learning process in order to give learners an opportunity to test their understandings, have them challenged by others, and through negotiation ultimately expand and deepen their thinking (e.g. Savery & Duffy, 1995; Duffy & Cunningham, 1996; Duffy, Dueber & Hawley, 1998; Wise & Duffy, 2008; Robinson, Wise & Duffy, in press). Thus, with LTTS we explored numerous strategies for achieving peer interaction and collaboration while staying true to our design commitments. We begin the discussion with a description of our design commitments and the rationale for them.

The Initial Design: Commitments and Consequences

LTTS was developed based on a set of design commitments that addressed theoretical, pedagogical, and practical issues related to professional development using inquiry-based learning (Duffy et al., 2006). Of particular interest to this chapter were our two commitments related to the delivery of instruction. The first of these was that the materials and learning experience must be relevant to the teacher's own classroom practice and teaching needs. The second was that the learning opportunity must offer ease of access and flexibility to the teachers. Below we describe each commitment, the principles used to instantiate them, and how together, they led us to an individualized learning design for LTTS.

Relevance to the Teacher

As discussed earlier, changes in practice are the ultimate arbiter of whether professional development has been successful (Bitan-Friedlander et al., 2004). Despite this goal, too often professional development courses concentrate on general principles and strategies in isolation from the participating teachers' classrooms, leaving the teachers with the task of applying and focusing those general rules to their own practice (e.g., Consortium for Policy Research in Education, 1997). Many teachers find this gap hard to bridge. Relevance of professional development to a teacher's goals and classroom needs has been widely included in professional development standards (e.g., Elmore, 2002; National Partnership for Excellence and Accountability in Teaching, 2000) and, in fact, Garet, Porter, Desimone, Birman, and Yoon (2001) identified this aspect as one of the three critical elements for professional development success. In addition, researchers have begun to see the benefits of teacher professional development that focuses on materials and understandings directly relevant to classroom activities (e.g., Banilower, Boyd, Pasley, & Weiss, 2006; Corallo & McDonald, 2002).

Because effective professional development needs to be relevant and an important aspect of relevance is helping teachers make connections between the learning material and their own classroom (e.g., California Comprehensive Center and American Institute of Research, 2006; Hill, 2004), designing professional development that was relevant to the teachers and their classrooms was one of our primary goals. We generated three principles to support our commitment to this goal.

First, the learning had to be situated in a teaching problem. We addressed the need for relevance by relying on classroom issues that teachers commonly encountered, particularly problems based on the curriculum and standards teachers must teach. We reasoned that if our courses helped teachers develop strategies to address their existing needs, they would be more likely to apply the professional development in their classroom. To ensure the selection of relevant course topics, we engaged a group of teacher developers on the first set of LTTS modules to help us identify areas of interest for courses based on their own areas of inquiry in their classrooms.

Our second principle related to relevance was that the system needed to provide choices so that teachers could find problems relevant to their particular needs with which to engage. In teacher professional development, one size does not fit all and not all curricular problems are relevant to all teachers at all times. Nonetheless, the content of traditional face-to-face professional development courses is often driven by a need for broad appeal and limited by the availability of the presenters at the scheduled time. The anytime/anywhere affordances of the web relax these scheduling and coordination restraints and allowed us to have experts develop courses when they had the time. In this way, we were able to create a large library of courses focused on teaching problems that we believed would be engaging to a variety of teachers. Thus, having a catalogue of more than 60 courses, many of them interdisciplinary ones, was an important aspect of the LTTS design.

The final relevance-related principle stated that the learning activities needed to focus on an outcome that could be directly applied in the classroom. Beyond simply changing practice over the short-term, this principle acknowledged that teachers needed support in taking the first (and perhaps most difficult) step toward modifying their classroom practice more generally. By implementing a lesson plan or unit they had created in a professional development course, they would build bridges between theory and practice and start to develop confidence in the new skills or techniques, an important factor mediating teacher change (Bitan-Friedlander et al., 2004).

Combined, these three principles operationalized our commitment to the importance of relevance in designing the professional development experience for teachers. The individualized online approach we took with LTTS provided a unique opportunity to embrace the relevance commitment in ways that were simply not possible in traditional group-based face-to-face professional development settings.

Flexible Ease of Access

Our second commitment related to the delivery of instruction focused on creating a professional development environment that provided flexible ease of access. Too often in professional development, accessibility issues reside with the commitment the teacher must make to the time and schedule requirements. Professional development requires teachers, who are often already overcommitted, to fit one more thing into their very busy schedules (Scribner, 2003). Because of the challenges of coordinating multiple teachers' schedules and the limitations in funding available to finance professional development, the bulk of experiences continues to be one-shot workshops (Parsad, Lewis, & Farris, 2001), even though there is strong evidence that sustained professional development is necessary for teacher learning and for impacting practice (e.g. Banilower et al., 2006; Richardson & Placier, 2001).

In order for knowledge and skills to internalize, teachers need time to process, experiment, and reflect on what they learn (Blumenfeld et al., 1991). Of course if the experience is too prolonged, their focus may be lost. Thus professional development experiences should occur over an extended but finite period of time. Specifically, Banilower et al. (2006), suggest a guideline of courses that are 30–80 hours in duration. While our LTTS courses were at the lower end of this range, we believe that the focused scope of each course and the ease of taking multiple courses allows LTTS to be considered as providing experiences that are in-depth enough and long enough to support teacher learning.

We formulated three principles for the design of LTTS to support our commitment to creating a professional development opportunity that provided ease of access and flexibility to teachers in the context of a sustained experience. The first principle was to provide focused courses addressing specific classroom problems that would fit within the time recommendations. We sought to walk the middle ground between full semester courses (to which teachers might hesitate to commit) and the one-shot experiences that are typically not effective for impacting practice. Thus, LTTS courses were designed to engage teachers in sustained work on a single curriculum issue that was limited in scope.

The second principle related to ease of access focused on creating a just-in-time model. Teachers need to be able to access professional development opportunities when the need arises or when they have time, not when someone decides to offer a course (or only when a critical mass of teachers are ready to take the course). Thus, LTTS courses were designed to be started at any time, with the products of the courses ready to be implemented in the classroom as soon as the course was completed.

Finally, our third principle related to ease of access and flexibility was that teachers needed to be able to work at their own pace. While online learning is often heralded for being available "any time, any place," what is most critical to teachers is "anypace" learning. Teachers need the flexibility to choose when to work (e.g., morning or evening) as well as to choose how to pace themselves (e.g., they need to be able to take a week off when there are particular demands at school, or perhaps compress work during a period of free time). Self-pacing was one of the unique affordances of the web-based approach we took with LTTS.

Individualization

Clearly, our commitment to the flexibility and relevance of the learning opportunity drove many of the decisions we made in the design of the LTTS approach to professional development. This is true both in terms of the specific courses that were created for the teachers and the design of the online system itself. Specifically, in order to maximize relevance and flexibility, LTTS was initially conceived as a system for individual self-study (note that the original design did not include a mentor). Teachers could come to the system at any time, search through the catalog of over 60 different courses to find one that addressed a teaching problem they found relevant, work through the course tasks at their own pace, and produce a lesson plan that was tailored to their needs and context, and could be directly applied in their classroom.

Providing this flexibility and relevance was not without tradeoffs, however. In adhering to our design principles, we faced a tension between the practical requirements of teachers and our theoretical beliefs about the importance of a peer-based collaborative learning environment. We recognized that a traditional "class" setting could potentially provide a learning community that would provide mutual support in the development of understanding and in motivating learning. Most importantly, we saw the peer group as serving to validate or challenge teachers' thinking about teaching, i.e., to contribute to the development of each member's identity as a teacher. However, our commitments to relevance and ease of access made group learning impossible. After all, it is not feasible to create flexible, individualized learning opportunities for a classroom or cohort setting.

While our commitment to learning anytime, anywhere, and at anypace was central, we also valued the impact of peer interaction and collaboration on the professional development process. We know that teachers have limited time and opportunities to share their questions or lesson plans. So as our first attempt to include peer interaction in the individualized LTTS system, we asked teachers to participate in an archived asynchronous discussion forum about their course. The idea was that upon completion of each task the teachers would go into an "Idea Sharing" space to post ideas related to what they had done and/or questions that had arisen for them. These discussion spaces were unique to the course and the task. The notion was that teachers taking the same course could support each other by sharing the thoughts, concerns, issues, and ideas they found important, even if they were not moving through the course together as a group. Further, they could share their lesson plans or pieces of them.

By designing LTTS in an individualized self-paced way, we asked the question of what teachers would do in a professional development system when given the opportunity (and responsibility) to direct their own learning and interactions. Would our task instructions and resources provide enough support to effectively structure teachers' work in the course? Would they take full advantage of the extensive resources we provided or would they use a minimal effort strategy? Would teachers be content to work on their own or would they feel a need to interact with "others" in the system? If so, would the discussion forums with other teachers taking the same course fulfill this need?

Evaluating the Initial Design

In 2001, we conducted a formative evaluation with 13 teachers using the LTTS system in its original self-study design without a mentor (Orrill, Calhoun, & Sikes, 2002). For the evaluation, the teachers were asked to select one course from the small set of courses initially developed and told that they should expect to spend about 10–20 hours on their work. (Note that this time suggestion does not match the time required by the current system due to changes in the structure of the courses.) During the course of the evaluation, two participants who indicated a desire for more feedback did receive limited, mostly motivational, feedback from LTTS staff.

This early design of LTTS had many features that were determined to be successful. The teachers reported that they found their overall experience valuable. In fact on a Likert-scale survey given at the end of the course, 9 of the 11 teachers who completed this survey reported that their LTTS experience helped them to become better teachers; all 11 of the teachers reported that they felt confident in their ability to integrate technology into their classroom; all of the teachers said they would recommend LTTS to a colleague; and 10 reported that they intended to use their newly developed product in their classroom.

As part of the formative evaluation, the teachers were asked what they found valuable and non-valuable about LTTS. Even in this early version, in which no support was provided by a mentor, participating teachers reported that they liked the self-directed approach (8 of 13), noting the value that the flexibility and convenience of the system provided them. In addition, seven of the teachers said that they liked creating a product that was useful for their classroom. Four teachers, however, said that a lack of a set schedule or some type of accountability was a challenge for them.

We also examined how teachers structured their work through the LTTS system. In general the teachers seemed to function well in the self-paced activity-oriented environment and nearly all set a schedule in which they completed their course for the evaluation in 4–6 weeks. They did not, however, capitalize on the flexibility of the system to skip between tasks, to see what was coming next, or to revisit previous steps. In fact, several of the teachers approached the tasks almost as a series of class assignments, completing exactly one each week. It is possible that this approach was influenced in part by the weekly interviews the evaluation team conducted, which some teachers reported kept them on track as they completed the course tasks. The teachers may have felt pressure to have evidence that they were working on the course for each scheduled interview even though the evaluation team never suggested a need for weekly progress to be made.

In this evaluation, we saw a typical user pattern emerge in the approaches teachers took to completing the courses. Based on our interview data, self-reports of time spent on each activity, and review of deliverables for each activity, all but two teachers seemed to take a very task-focused approach, simply fulfilling the requirements for each activity and submitting their work. They seemed not to see the course as an opportunity for deep and rich learning; rather their work was very product-driven. Thus instead of engaging in exploration and a development of understanding as we had intended, these teachers focused only on the basic information they needed to complete each task in the course. In fact, the teachers spent an average of only 8.5 hours on the courses compared to the expected 10–20 hours.

In contrast, one teacher who did engage with all aspects of the learning opportunity spent approximately 33 hours on the course. Unlike most of the other participants, she capitalized on this as a learning opportunity by reading all of the information provided, conducting her own classroom research as part of her development process, and talking to her co-teacher about her work in the course. While this teacher sought outside feedback on her work in the course, most teachers did not seek or receive this kind of guidance. As already mentioned, only two teachers received any feedback from a mentor – and that feedback was focused on maintaining high motivation rather than engaging the teachers in critical reflection or deeper learning.

Without guidance and feedback on the quality of their work, most of the teachers were left to their own devices to gauge their process and products. This led some to make decisions about the quality of their work based on the examples they saw in the resource links provided for each course, while others simply went by how pleased they were with the products they were generating or how much time they had spent on the course. The teachers did not use the goals of the course or the self-assessment tools to determine whether they were "on the right track," nor did they use the provided discussion boards to ask questions or otherwise engage with the other teachers taking the course.

There were some practical issues that contributed to the lack of use of the discussion forums in this first iteration of the system. For example, some teachers experienced technical difficulties when they tried to use the forums. In other cases, teachers were the first (and only) person to enroll in the course. This meant that the forum was empty when they arrived and that there was no one to reply to any post they might make. While little use of the forums was seen, the participating teachers commented that they would have found the discussion forums useful if there had already been responses posted when they arrived. In short, the initial LTTS design really did not support teacher interaction effectively.

The lack of interaction and feedback during the evaluation may explain a troubling issue that emerged. The participating teachers often reported that they were satisfied with their course products; however, the LTTS team felt that many of these products did not meet LTTS expectations. One consideration was that in the majority of the courses completed for this evaluation, the teachers focused on integrating technology into their classroom without changing their teaching practices, one of the major goals of LTTS. This was reflected in their final lesson plans, which included technology as something fun or useful, but not as an integral instructional tool for the lesson.

A second issue in these course products was inadequate depth in the description of the lesson plan and a lack of rationale for the choices made in the plan. It seemed that without a true external audience, or the expectation of feedback, there was not enough structure to support the teachers in pushing themselves to make their thinking apparent. One of the major challenges related to this point was that to implement the lesson plan, the teacher would need to be able to make sense of it at a later time. Without adequate information, they would only have skeleton of a lesson to work from which might lead to further degradation in the quality of the inquiry and technology integration.

A third emergent issue related to the lack of feedback was teacher frustration with the culminating activity of each course. Once the teachers had completed each of their tasks they did not value the final step, which was to combine them into a lesson plan. With no external audience, the teachers in the evaluation reported that they did not see a value in pulling the deliverables for each of the tasks together into a final form. However, the LTTS process had assumed that this would be a task that would allow the teachers to both refine their previous work and to reflect on their learning and their product.

Looking at these three issues together, the teachers who engaged in LTTS on their own seemed to be applying the notion of a “make and take” experience to the LTTS environment. While a make and take workshop focuses on simply creating a product that can be used immediately in the classroom, LTTS was designed to help develop conceptual knowledge that could both be embodied in the product of the LTTS course and applied to other lesson plans in the teachers’ classrooms. The teachers in the formative evaluation did not appear to perceive or appreciate this distinction. This is an important difference as make and take workshops do not follow the fundamental standards for professional development because they are not sustained, not grounded in relevant activity, and not focused on meeting classroom needs in the service of supporting teacher learning. Rather, their goal is simply to give the teachers something new to try out in their classrooms. It appeared in this first evaluation that in order to move teachers away from completing professional development as a pro forma experience and toward thinking about it as a deep learning event, more real-time personalized guidance was needed.

The teachers themselves also highlighted the need for greater support. While they indicated that they valued the self-pacing of the system, six of the teachers who said they liked working alone also said that they would have liked some feedback and/or collaboration. Ten of the thirteen teachers, including those six, said that they disliked not having feedback and/or collaboration. Conversely, the two teachers who did receive feedback both said that they liked it. Further, even though they did not take advantage of the (limited) opportunities for peer interaction provided in the system, several teachers explicitly commented that they would have found interacting with other teachers to be valuable.

At the end of this initial evaluation, we were sure that our two design commitments, relevance and flexibility, were worthwhile and promising in the design of the LTTS system. We saw that teachers could and would engage in a self-paced online learning environment to create products that were relevant to their teaching and that these teachers enjoyed the opportunity and found it valuable. At the same time, we felt that, in order to maximize the learning opportunity, teachers needed some kind of interaction to provide accountability and to give suggestions that would push their thinking and engage them in reflecting more critically about their work. Our task as designers was to determine the best ways to address these challenges without compromising the commitments to relevance and flexibility that formed the foundation of the LTTS approach to professional development.

Integrating Interaction in Anytime, Anywhere, Anypace Professional Development

In response to the needs revealed by the formative evaluation, in the next iteration of the design we sought to fulfill the functions of accountability and feedback by introducing mentoring and enriching the opportunities for peer collaboration. Mentoring was an attractive approach from the perspective of maintaining our commitments to relevance and flexibility. Mentors were assigned to individual teachers taking courses, allowing feedback to be customized for each teacher both in terms of relevance and timing. The mentor's role was designed to fulfill both of the interaction needs described above: first, having a person to whom work is submitted provided an incentive for teachers to make their thinking explicit; second, the feedback from the mentors on the activity submissions pushed the teachers to think more deeply about their work. Note that from the start, the mentoring reflected our pedagogical commitment to an inquiry-based approach to instruction. That is, we did not want the mentors to tell the teachers what to do, but rather to focus on asking questions. This design was also cost effective as the approach of asking probing questions kept mentors from getting bogged down in the details of trying to redesign the lesson themselves, and allowed a single mentor to work with many teachers at the same time.

Our mentoring strategy was very successful and changed little from its initial introduction to the final system described at the beginning of this chapter. In fact, the only substantive changes in the mentoring process were the design of administrative tools to support mentoring (del Valle & Duffy, 2005) and the development of a formalized mentor training process. In our recent evaluation of the final version of LTTS (Duffy et al., 2006), teachers overwhelming reported that the mentor was a helpful and valuable feature of the system. In the post-course survey, 92% of teachers agreed or strongly agreed with the statement "the mentor was a big help to me in this course" and in the open-ended question asking what was the most helpful feature of the course, mentoring was the most common answer (44% of responses). The mentoring was also the second-most common answer to the open-ended question of what teachers liked most in their course (20.5%). In short, the need expressed in the initial evaluation of the system was addressed and teachers highly appreciated the form the solution took.

These findings about the mentoring feature are particularly interesting given that the overall level of mentoring in the system is low, with each teacher receiving only about 3.5 hours of mentoring. This includes time spent by the mentors reading teacher submissions and composing appropriate feedback. Assuming that teachers take the same (or less) time to read the mentors' comments, this is a relatively small percentage of the typical 30 hours teachers spent working on a course. However, the fact that the teacher's work, and hence the mentor's feedback, is focused on the teacher's own lesson plan greatly enhances the value of the feedback relative to the typical situation in which the teachers' work (and, thus, the feedback) centers around a more generic teaching task. The relevance and value of the mentors' feedback are reflected in the high percentage (50%) of submissions by teachers that are revised and resubmitted based on feedback, even though revision is rarely required by the mentors. Again, the design of LTTS embodies the professional development standards as relevant to the teachers; the evaluation findings show the power that this relevance has on teacher satisfaction and perceived learning.

In our experience with LTTS implementation, we saw some additional mentoring roles emerge. For example, mentors began to provide a friendly and supportive atmosphere. We tested the importance of this role in an experimental study that had mentors provide a uniform level of feedback, but with variations in the friendliness of communication or "social presence" (Wise, Chang, Duffy, & del Valle, 2004). Though teachers perceived the difference and responded in kind (with friendly or efficient messages, respectively), no effect on satisfaction, engagement, or the quality of the final course product was observed. It may be that the simple presence of a human mentor fulfills the need for sociability, regardless of their level of friendliness, or that LTTS learners were not looking for extensive social interaction; but simply a rich learning experience. The extent to which this finding generalizes to other populations of online learners is a question worthy of further inquiry.

The presence of a mentor also provided a general sense of accountability, which may have influenced how teachers worked through the materials provided in the LTTS courses. We recently conducted an analysis of the work patterns of teachers in LTTS based on the overall time and frequency of work put into the course, proportion of resources accessed, use of mentor messages, and fluidity in moving between course elements (del Valle & Duffy, 2007). The overall results indicate that, in fact, teachers took advantage of the flexibility offered by the system, especially the ability to work at their own pace. Looking at 59 teachers who completed their courses, we saw 3 distinct learning approaches, as expressed in their work patterns.

The majority (59%) took a mastery-oriented approach to their coursework, putting in an intense and sustained effort, taking advantage of many of the courses' resources, and moving fluidly between course elements. In contrast, 22% exhibited a task-focused orientation in which the course was successfully completed, but with less intense work over a shorter period of time. This is a strikingly different pattern than seen in the formative evaluation of the non-mentored version of the LTTS courses in which 10 of the 12 participants (83%) were task-focused and only one participant exhibited a mastery-orientation.

Since these were separate studies using different populations and measurement techniques, we cannot make causal claims about the difference observed, however, we do note that the addition of the mentor was the only intentional change made to the courses between the studies. An experimental study using the current system in mentored and non-mentored forms could confirm the presence of an accountability effect on teacher's self-directed work patterns.

The remainder of the teachers in the recent work-pattern study (19%) exhibited what we described as a minimalist approach to their coursework, though they did successfully complete their courses. They took many calendar days to do their work, but spent the least amount of time online as compared to their peers, and used a very small proportion of the resources provided. In our investigation of what characteristics might differentiate this group of teachers from the others, the only significant difference we found was their self-reported preference for working with a group (del Valle & Duffy, 2007). This may reflect a need for motivation and community or possibly a need for more direction and structure.

To address the need for collaboration expressed by the minimalist group in the work-pattern study, we planned several strategies to introduce peer collaboration into LTTS while maintaining our commitments to relevance and flexibility. Our first strategy focused on the use of the course-specific "Idea Sharing" discussion forums for each task. While unsuccessful in the formative evaluation, teachers' comments indicated that this was possibly due to a lack of critical mass of teachers in the courses – in the early evaluation of LTTS, there were simply not enough teachers to seed the discussion boards for each task in each course, therefore when the participating teachers visited the boards, there was nothing there for them to read. We thought that as LTTS grew its user base, these discussion forums could become a valuable resource for teachers.

We also created general discussion forums that were available to learners in all courses at all times. These forums were organized around relevant topics (such as "Technology Integration and Professional Development," "Inquiry-Based Teaching," and "Curriculum Standards") so that teachers would be able to find discussions of interest to them. Teachers could respond to existing threads in each forum or initiate new ones. This was a complementary strategy to the task-specific "Idea Sharing" discussions since the general discussions were less tightly coupled to the teachers' work in their course, but drew on a greater population base (all teachers in LTTS as any given time) and thus were more likely to generate discussions with real-time responsiveness.

Unfortunately, both kinds of discussion forums languished, unused, and seemingly unvalued. Teachers saw the "Idea Sharing" discussion boards for each task as busy work. They had already submitted their work to the mentor, who they knew would respond promptly with relevant comments. The possibility that a fellow teacher *might* respond to their posting in a discussion board in a timely fashion with ideas that *might* be useful was not seen to be worth the effort of posting after each task. Even when we had the mentors specifically encouraging these contributions in their messages, teachers responded perfunctorily if at all.

The feedback on the general discussion forums was also decidedly negative. Teachers were focused on completing the tasks in the course, the mentor was supporting them in that goal, and their work in LTTS was relevant to their classroom. From the teachers' perspectives, more general collaborative activities such as participating in the topic-based discussion boards distracted them from their very focused work on their course product.

If the discussion forums seemed extraneous to the teacher's coursework and professional growth, we posited that perhaps there would be more value if teachers were working through a course together. Instituting a group or cohort version of the course would necessarily reduce some of the flexibility we had designed into LTTS, but might prove attractive to those teachers desiring collaboration. In terms of relevance, we faced a tradeoff in supporting teachers in work that was directly relevant to their own classroom and providing them with a common focus for relevant discussion.

To address this tradeoff, we offered two different versions of a group form of the course. The first strategy we employed was to recruit teachers for some of our most popular courses to work on a lesson plan together. The idea was that by allowing teachers to self-select the course, we would still get a group that saw the course as relevant. The second strategy we tried was a consultative approach, similar to the Learning Circles model (Riel, 1995) in which teachers taking the course together would each work on a lesson for their individual classroom, but provide feedback to each other on their lesson plans. By doing this, the teachers would have the opportunity to develop a community of practice (Lave & Wenger, 1991; Wenger, 1998) in which they would simultaneously learn from and support each other.

Unfortunately, despite our attempts to offer these group versions of LTTS courses on multiple occasions, we were unable to recruit enough participants to run even one group. At the same time, we continued to have plenty of enrollments for the individual self-paced version of the courses. This was true even when we offered compensation for participating in the research study. Teachers explained their refusal by citing different schedules, overall workload, and the fact that with the very specific individual learning goals they had for their professional development, they felt that they would be more efficient working individually. It seems that the need for relevance and flexibility trumped the desire to work with other teachers.

The supreme importance of relevancy and flexibility to teachers taking our courses was highlighted in our recent evaluation. The evaluation looked both at what initially attracted teachers to LTTS and what they found important in their course experience. When asked an open-ended question during the initial registration about why they chose to take an LTTS course, two main reasons accounted for over 50% of teachers' responses: relevance to their needs (26.8%) and flexibility (29.1%). The flexibility afforded by the self-pacing was also the most common answer (33% of responses) to an open-ended question in the post-survey that asked teachers what they liked most in the course.

Additionally, on the Likert-scale post-course survey 94% of the teachers agreed or strongly agreed that the self-pacing in the course was important to them.

Adhering as closely as possible to the principles of relevancy and flexibility, we made one final attempt at peer interaction in LTTS. After eliminating the "Idea Sharing" forums for each task in a course and the general topic discussion forums, we created a single forum for each course called "Learning Experiences." These were not discussion forums in the traditional sense but rather a public space to collect lessons learned from teachers as they finished the courses. Just before they submitted their final product, teachers were asked to share advice to help teachers starting in LTTS to get the most out of the course. A link to the space was provided on the home page for each course to allow teachers at the beginning of the course to benefit from the advice of those who had already completed it.

Teachers have readily contributed to these forums with a wide range of comments, highlighting important pedagogical questions related to the course content, and sharing practical strategies for managing the workload. As with all of our design decisions, however, a tradeoff was made. In our effort to maintain the flexibility clearly valued by teachers in LTTS, we sacrificed true collaboration. These forums do not lead to the testing or negotiating of understandings that we see as valuable in the learning process. They do, however, serve the pedagogical function of encouraging reflection on the learning process, and they provide the opportunity for teachers to benefit from the wisdom of those that have come before them.

Lessons Learned: The Role of a Peer Group and Balancing Design Commitments

A peer group can potentially provide many benefits to professional learning. The presence of others can provide a motivating social environment, drive learners to more fully explicate their thinking, push them to consider different perspectives, and allow them to negotiate a deeper understanding. It can also provide a community through which the learners develop their identities as professionals. Of course these pedagogical functions are not guaranteed to occur simply because a peer group is present. Further, while there are potential benefits of a peer group, the presence of peers can also be distracting when they provide a positive social experience without any real learning. Indeed, it is important to distinguish between learner satisfaction and actual learning.

While many suggest (e.g., Collison, Elbaum, Haavind, & Tinker, 2000; Salmon, 2000) and have found (Mikulecky, 1998) that rich discussion and collaboration is possible in an online context, it is not easy to reach that level of interaction. Even in well-designed environments with cohort-based courses, other practitioners and researchers have experienced the same lack of contribution to online discussions observed in LTTS (e.g., Hara, Bonk, & Angeli, 2000). Further, other researchers have also noted that participants often tend to post without replying to other participants' contributions (e.g., Collett, Kanuka, Blanchette, & Goodale, 1999) and threaded discussions often end with several members having acted only as passive observers (e.g., Klemm & Snell, 1996). Clearly, setting up an online forum for learners to converse does not guarantee any learning benefits.

Thus the question of whether or not a peer group should be designed into a learning experience is subservient to the larger questions of what pedagogical functions are needed to support learners in the particular environment and what the most effective ways to fulfill these functions might be, given other commitments and constraints. Our pilot evaluation of LTTS demonstrated a need for accountability (for motivation and explicating one's ideas) and feedback (to push the thinking). While both a mentor and a peer group could fulfill these functions, a mentor was better able to do so without sacrificing our commitments to relevance and flexibility.

The mentor also had the advantage of being someone who was specifically tasked with thinking about and addressing the teacher's classroom. Teachers enrolled in LTTS courses were focused on their own issues on their own timeline and wanted someone else who was too. Such a narrow focus can lead to problems in "collaborative" discussion where, due to the lack of common ground, teachers end up talking past each other (Carroll, Rosson, Dunlap, & Isenhour, 2005; Carroll et al., 2003). When one teacher talks about his or her class and design goals, the other teachers can hear the explicit surface description of what is being said, but they do not share the deeper tacit understandings that underlie it. Because of the different ways teachers set up their classrooms and work with their students, and each teacher's focus on their own context, other teachers may interpret the speaker's statements very differently than how they were intended. We have argued previously that if professionals do not share a common reference point to ground their conversation, then practice-based discussion will result in miscommunication in which words are exchanged but meaning is lost (Wise & Duffy, 2008; Wise, Duffy, & Padmanabhan, 2008). For collaborative discussions between teachers from different contexts to be meaningful, some common ground is needed. We have begun to experiment with providing reference point classrooms for teachers to use in conversation, and have found that the design of these aids is critical to how they are used (Wise, 2007).

What of the other functions that a peer group might provide – a motivating social environment and a community through which teachers can develop their professional identities? Our experimental research varying the social presence of the mentor indicated that in this context the simple presence of someone else, regardless of that person's level of sociability, provided a sufficiently motivating social environment (Wise et al., 2004). The real value of the mentor came from the feedback he or she offered, not their overall friendliness. This finding has led us to question the value of sociability as it is often promoted in peer collaborative environments. Of course this is a hypothesis to be tested, and, if the social activities are designed to foster trust or some other factor expected to affect collaborative learning, then positive effects may be found.

We are left with the question of a community for identity formation. Only a small percentage of the teachers in our final evaluation indicated a desire for a peer group in addition to their mentor. When group versions of our courses were offered, we were unable to get enough participants for even one group. Teachers' desire to take a course that was relevant to their needs and that could fit their schedule seemed to outweigh their desire to work with peers. Perhaps we should not be surprised at the lack of priority teachers placed on working with a peer group. While it is clear that there is tremendous value in teachers working together toward a shared learning goal (e.g., Kazemi & Franke, 2004, Sherin & Han, 2004; Rogers et al., 2007), this approach is still very foreign in the work lives of teachers. We further compounded the newness of working with peers in our initial attempts to promote teacher interaction in an environment (the online system) that was unfamiliar to them.

Despite widespread efforts to change the culture of teaching, too often, teachers still work in isolation (e.g., Fulton, Yoon, & Lee, 2005). We assert that this culture of isolation underlies the findings of our recent evaluation data which found that only 27% of our participating teachers agreed or strongly agreed that they would prefer going through the course with other teachers and only 10% of the teachers mentioned the lack of interaction with other teachers as a problem when asked if there was anything they would change about the course.

Conclusions for LTTS and Beyond

We still feel strongly that in many situations a social context is important for motivating learners, presenting challenges that promote learning, and providing the context for identity development. However, in the particular context of LTTS, we have found that individual mentoring, rather than a peer group, works better to meet those goals. This conclusion was certainly shaped by our teachers' rejection of almost all attempts to not only create peer group interaction and collaboration, but also indicate our emergent conceptual understanding of the shortcomings of peer groups and the value and efficiency of individual mentoring in supporting teachers in meeting their goals.

We believe that there are two contextual variables that impacted the role of collaboration in LTTS: the current status of our participants as teachers and the personal relevance of the learning task. First, we assert that the teachers have already established their basic identity as teachers and thus, we believe, a more knowledgeable other (the mentor) will be at least as effective as a peer group in supporting their learning and in promoting the further evolution of the teacher's identity. Teachers may not value the input of peers as much as people who they perceive of as more knowledgeable or more experienced.

Perhaps more important than teacher identity, however, the personal relevance of the learning task and the fact that the learning task is different for each teacher (each has his or her own classroom needs) are key factors that make the collaborative learning environment less effective, perhaps even distracting, in this situation. The individualized learning task was relevant and motivating for teachers. They did not need peers for motivational purposes simply because the work had already engaged them in the learning. Additionally, because we designed the courses to specifically apply to each teacher's individual classroom, communication among peers at a level of detail that supports learning in the context of that task would be very difficult (Wise & Duffy, 2008).

We contrast this to the more common learning environments in which learning tasks are not personally relevant but rather involve learning principles for later application. A peer group can be very effective in this situation because members of the group can provide examples of application of the principles at a very general level. However, we question whether these more general learning tasks are adequate for teachers to apply the principles effectively in their classrooms. It is much like a textbook: great for learning at a general level but when it comes to real application the necessary details are missing (Barrows, personal communication).

We also contrast the LTTS context to the more typical problem-centered learning situations in which a team of learners work on a problem that is relevant to all members of the team. In this case, there is a shared reference point for all team members. However, in teaching, there are few authentic settings of this kind. One notable exception is Japanese Lesson Study in which a group of teachers work to develop, implement, and refine a single lesson that all of the teachers will eventually use (Fernandez & Chokshi, 2002; Fernandez, Cannon & Chokshi, 2003).

In sum, through our iterative development process, we were able to not only develop a robust learning environment that supported teachers in learning to integrate technology in inquiry-oriented ways, but also to refine our understanding of the role of collaboration in the learning process. At the beginning of this 9-year effort, we did not anticipate having our beliefs and understanding about collaborative learning challenged in this way. However, LTTS provided a rich learning environment not only for our participants, but for us as designers and researchers as well.

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Linking the POV-ing Theory to Multimedia Representations of Teaching, Learning, Research in the Age of Social Networking

Ricki Goldman and Chaoyan Dong

Abstract This theoretical chapter is a call to reconnect the underlying epistemologies of learning, teaching, and research through a deeper understanding of the synergies of layering shared perspectives and multimedia environments – in other words, *the points of viewing theory* (POVT) meets *multimedia representations of teaching, learning, and research* (MRTLRs). Until recently, Goldman-Segall's points of viewing theory provided digital video ethnographers with a framework based on the sharing of perspectives for validity. We scale-up this perspective theory to explain how, in the age of social networking – learners', teachers', and researchers' roles become more permeable through the collaborative process of *layering viewpoints*, analyses, and interpretations. Closing remarks discuss the importance of reconstituting the three parts of educating within social networking technologies spaces – the corner-store where learners hang out. Layering perspectives and the ability to create meaningful knowledge for self and others in social networks is the next frontier in the future of designing, using, and critiquing technologies for learning.

Keywords Multimedia · Digital video · Perspectivity · Points of viewing theory (POVT) · Social networking · Multimedia representations of teaching learning and research (MRTLR) · Laying viewpoints · Instructional technology · Learning networks · Collaboration · Constructivism · Layering · Critical thinking · Reflection

Introduction

Thirty educational researchers, teachers, and teacher educators presented their position papers and ideas at the Carnegie Center for the Advancement of the Scholarship of Teaching in the Professions at Stanford University in March of 2008. The event was hosted by Former President of the center, Lee Shulman

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whose work on *pedagogical content knowledge* has become the gold standard in understanding how teaching is a not just a method to be taught, but a pedagogical content area to be constructed. The focus of discussions at the gathering was to understand the current and future use of *multimedia records of teaching* (MRTs)[1]. As a member of the gathering, I proposed the term, MRTL, *multimedia representations of teaching and learning* because multimedia representations not only change how we teach, but also how we learn and conduct research. Moreover, in technology-based learning environments[2] teachers become learners and researchers, learners become researchers and teachers, and researchers often become participating learners and teachers (Goldman-Segall, 1998). In this chapter, we introduce the term MR-TLR, *multimedia representations of teaching, learning and research,* to describe a paradigm shift that occurs when learners, teachers and researchers change roles when learning how to create and share their perspectives of multimedia representations.

Let us first frame the problematic relationship that exists between learning and teaching with a quote by anarchist educational critic and philosopher Ivan Illich: "Most learning is . . . the result of unhampered participation in a meaningful setting" (1971, p. 44). In 1972, I received a marked-up, yet unpublished manuscript that Illich was passing to friends of friends of friends to read and send back with commentary in the margins of the pages. He had coined the term *learning webs* in his famous *Deschooling Society* (1971) and was, in this act of sharing his new manuscript on conviviality, using the tools available in his time – one could say the passing of text on paper through a social network – to (1) engage others in issues, (2) share knowledge, and (3) provide access to resources. Indeed, he proposed these three principles as the basis for a good educational system (1971, p. 78). His disillusionment with schooling (teaching) and his call to deinstitutionalizing schools were probably a means of freeing societies from all forms of institutionalization.

We want to use Illich's provocation to suggest another possibility – that learning, teaching, and research have never been separate entities, but rather partners within the same education process. The intertwined roles of learners, teachers, and researchers are reinforced in Lemke's theory of human ecosocial system (2002) that people are linked together through social networks. He argues that, "'It takes a village' to study a village. ... There is perhaps some hope insofar as distributed communities of researchers, linked by new communication networks and technologies, may grow to become such "villages" and

[1] Multimedia *representations of teaching* is a term used both by Magdalene Lampert and Deborah Ball (1998). The Carnegie Foundation gathering used the terms *multimedia records of teaching* and *multimedia representations of teaching* as interchangeable constructs.

[2] For the sake of clarity, all mediated worlds – online video tools, electronic games, interactive websites, wikis, virtual online environments, and the full range of social networking tools – will be termed "multimedia." For those of you who consider multimedia and hypermedia out-of-date twentieth century terms, we beg your indulgence.

continue their work over the timescales needed" (p.288). The case is true not only for researchers, but also true for students and teachers. It seems simple enough to say this in 2008. However, the education profession has divided these three endeavors for a century. The twentieth century mindset did not pay attention to the permeability of each. Instead, each of the three main activities in the education process was seen as boxed into a separate container.

In this chapter, we place permeable skins around each wooden box and then carefully remove the wood to reveal three interconnected and continually interacting parts of the same entity in a human ecosocial system. The guiding thesis is that whenever we teach ourselves (or others) something new, through engagement with the natural and constructed world around us, we experience being teachers, learners, and researchers. Learning from oneself and making meaning of experiences is a process we need to better understand as more and more children and adults use a range of multimedia environments, especially environments such as online social networking. Educating (teaching, learning, and research) speaks to the relationships we form not only with each other within a culture, a society, but also within our real and virtual worlds when we both access (and ensure the access of others) to resources that allow knowledge to be continually constructed by learners of any age, gender, race, socio-economic background, or geographical location.

One defining affordance of MR-TLRs is that the process of learning, teaching, and research for educating[3] is no longer only a local concern, but rather a global one. To solve urgent ecological and political problems, researchers, teachers, learners along with all concerned citizens are compelled to engage in issues, share knowledge, and provide access and ensure access of learning resources on a global level. Another defining affordance of MR-TLRs is that they are not only used for connecting people in different parts of the world, but also for recording and keeping records of *the growth of learning cultures* (Papert, 1980; Goldman-Segall, 1989) so that the educating community can continually see and read, comprehend, interpret, and make meaning of what worked and what did not, under what circumstances, and from which combination of cultural, national, or ethnic perspectives and frameworks.

What is the *points of viewing theory*? Perhaps the best definition appears in the 2007 book called *Video Research in the Learning Sciences*:

> The *points of viewing theory* (POVT) has, at its heart, the intersecting perspectives of all participants with a stake in the community. It is a theory about how the interpretive actions of participants with video data overlap and intersect. To embrace how these points of viewing converge (and diverge) leads to a deeper understanding of, not only the event and the video event, but also the actual physical and the recorded context of the topic under investigation. The theory overcomes the static, isolating, individualized approach to point of view, in favor of the dynamic tension that operates among points of view, points that generate intersecting *sight-lines*, enabling people to catch sight of

[3] The term educating is used to refer, not to the institutional product, but rather to the process of learning, teaching, and researching.

> each other, as interpreters, even as they project their own point of view. In this way, the points of viewing theory underscores the importance of attending to how others project meaning on events. While attending to intersecting data of viewer and viewed, every interpretive action has the possibility of infusing meaning which creates new representations that ... resonate with the reasonable nature of members of a larger community. (Goldman, 2007, p. 508)

In research settings, sharing perspectives about media-based representations is the basis of reaching *configurational validity* (Goldman-Segall, 1995) in video-based studies. According to Goldman-Segall, *layers* of descriptions, analyses, and interpretations are "added" to the digital video data within multimedia analysis environments to create *thick description* (Geertz, 1973) – or what Goldman-Segall (1998) also calls *thick interpretation* and *thick communication* – in order to find patterns within the coding of data. In educational settings, sharing perspectives with multimedia representations of teaching and learning may be one very good route to more vivid and valued *pedagogical content knowledge,* to use Lee Shulman's PCK framework (1986). Layers are also about thickness and richness, although they also enable teachers and learners to find strategies for making meaning of the enormous amount of knowledge being socially constructed in ways that are permeable and reconfigurable.

Multimedia representations become *convivial* learning networks, as Illich (1971 and 1973) would say. Whether face-to-face or virtual, educational networks become cultures where teachers and learners engage with each other and within their local and global communities in collaborative investigation to address issues that are or will become meaningful to them. They are activities that are shared cooperatively by all members of the community. Or, as Young, Barab, and Garrett (2000) have advocated, teaching and learning are "the social negotiation of practice" (p. 149), in which "meaning is negotiated, goals emerge from social processes, and success is taken within context" (p. 160). Collaborative constructionist cultures are spaces and places where teachers, students and researchers become partners, not only to build knowledge together by accessing curricular content and technological resources to reach new insights, new methods, new tools, and new solutions, but also to *layer* their viewpoints of visual, aural, and intertextual representations.

What is meant by this term, *layering* (Goldman-Segall, 1994 1996)? Multimedia records become *layered* (and also searchable) interpretations and archives of knowledge created, shared, reused, and reconfigured in much the same way that Illich's manuscript was marked-up and sent from reader to reader. Except better. Knowledge as representation is always being constructed from diverse points of viewing, which others may reuse to construct new meanings and representations as now commonplace in social networking environments. This is especially witnessed in the self-correcting process of adding information to Wikipedia^{TM}, which leads to robustness of content as users add layers of information to this collaboratively constructed online encyclopedia.

Are Multimedia Representations New?

Are multimedia representations fundamentally "new" or are they simply more fluid and permeable expressions, creations, and constructions that enable us to cross real and virtual boundaries with more current tools? Let us briefly review the history of visual evolution. Human beings have always used diverse media, especially visual and verbal media, to communicate with each other and to learn (Gordon, 1977; Levinson, 1997). In prehistoric times, our ancestors communicated ideas, experiences, feelings, observations and interpretations of events with sounds, drawings, gestures, or engravings on wood, stone, parchment, or any other object available to them that could be manipulated to convey a message. The use of simple objects enabled knowledge to be "captured" in a form that stood for something other than the material from which it was created. In other words, signs or icons on objects (and the molding of objects themselves) became representations or artifacts of the "thing" it stood for. Each representation re-presented what it stood for. And, its purpose was to enable people to turn intangible experience into the tangible – something *external to* the body. It also enabled people to view and share creations and perhaps understand each other's experience. For example, early signs on rocks directed nomadic peoples to places they could find water. People today go to plays, concerts, galleries, and even car shows to experience a concept that has been developed and then made tangible for others.

Over time, peoples in different parts of the world codified speech in different ways and inscribed their *parole* into *langue*, languages that could be learned from each other in conversation, through immersion in texts, and within an instructional and constructionist setting. Written words stood for sounds, objects, ideas, and ways of presenting and marking what had always been, as Illich and Sanders (1988) pointed out, fleeting and ever-changing. For most peoples the seeming fixedness of the words and images captured on stones and other "media" gained more importance as "the truth" than utterances, parole. It also holds true that digital media in the twenty-first century paved the way for representations to be captured and shared for a period of time on ever-changing vessels (media forms) that store and make accessible the accumulated communication and learning of communities, peoples, and countries for a time and in a place.

With the evolution of visual communication tools and written languages, knowledge can be transferred and, if compelling, used by others. Each communication act builds multiple interactive episodes that created, not only *layers of meaning*, but also *patterns of interpretations* and *emergent creations* that can be recognized by others within genres and classifications. As we know, within time, one such expressional object (artifact) can stand for an entire discourse community or several interconnected ones – for example, the golden calf, a painting of a pond with water lilies, or a specific hand gesture.

With the invention of a printing press with moveable type in 1450 AD, what we now call the Gutenberg Revolution, knowledge suddenly became accessible to those who could afford to buy mass produced books instead of ones that were painstakingly hand-written. One could infer that the institutionalization of public schooling, an institution that has primarily used printed documents in almost every aspect of transmitting and testing learning, would most probably have not emerged without the Gutenberg Revolution as media scholars have pointed out (Jenkins, 2004; Moos, 1997; Thorburn & Jenkins, 2003).

In the twentieth century, "media" technologies – telephone, film, television, computers, and the World Wide Web – were employed to enhance communication. Within multimedia formats, broadband digital video with its richness for viewing the actions of real events and for presenting stories, captured the imagination of educators – not simply as a supplement to fill in time in a high school classroom at 2:00 pm on a Friday afternoon as was the case in the latter half of the twentieth century, but as a rich *environment* for viewing, reviewing, annotating, and then selecting elements or chunks for future use in a larger dynamic and interactive project. The oddly coherent nature of new visual media, even in its raw form with no editing, enables viewers to feel like one is present (Mirzoeff, 1999) and that *there is here*, whether we are in the process of learning, teaching, researching, or at play.

Clifford Geertz (1973) and other anthropologists refer to this phenomenon as "being there." It is what ethnographers try to create in the construction of written texts. Using digital video, the critical element in multimedia representations, creates a sense of deeper presence, increased immediacy, and almost complete engagement. Holding the digital camcorder, we play with the notion of virtual presence in much the same way that Woody Allen did in his movie, *The Purple Rose of Cairo*. Like Jeff Daniel's character, the dashing Tom Baxter who walks off the screen into the arms of Mia Farrow's character Cecilia, visual boundaries become permeable constructs. In *Second Life*^{TM} and *Facebook*^{TM}-like social networking environments, a sense of presence and a range of activities and interpretations can be layered as those who inhabit those spaces build more complex cultures.

The Importance of Video in Multimedia Representations

Video once conjured images of cramped editing rooms piled high with videotapes and video editors sitting in darkrooms for days. In fact, that was life until the late 1980s and early 1990s. Video is no longer restricted to a video-editing suite. It has come out of the confines of a darkroom and is now integrated with every byte of the computer. In fact, digital video on the desktop and video camcorders have become so pervasive that it is impossible to open a website without video excerpts streaming into your space. Or go for a walk in an urban setting without being videotaped. In classrooms and informal settings throughout the world, learners create video projects, teachers and pre-service teachers analyze video cases, and, researchers from all knowledge domains collect and interpret videotaped observations. However, some school administrators of educational institutions often ask why learners and teachers need to work with video. They are worried that there is not the time to incorporate yet another time-consuming activity into an already cluttered schedule. They ask what educational value video may have – except for those students who will become video artists or enter the entertainment industry. The reason they ask these questions is that they still use the model of video being a consumer product and a professional filmmaker's tool. They have not realized that video is not simply an aid to remembering something that might have been forgotten. The way a parent danced at a wedding. How the kittens were born. Instead, video is a window into learning about self and others. It is a tool to become a better learner. And, it is an environment for understanding the construction of cultures.

There is a caveat. When the video is selected for use in learning, teaching, and research, it fundamentally changes the learning environment. What was once private is immediately public. It is the Humpty Dumpty story all over again. *All the kings horse and all the kings men could not put Humpty Dumpty together again*. Once video, as multimedia presentation, is integrated into the classroom, the doors are never closed again. What existed before this "exposure" can never be reconstituted. And indeed, as the case studies in the chapter called *Gatekeepers of Horseless Barn* in the book, *Points of Viewing Children's Thinking: A Digital Ethnographer's Journey* (Goldman-Segall, 1998) remind us, researchers' participation changes. With each private space becoming public, the lines between self and other, inside and outside, sacred and profane, day and night, ad infinitum are crossed. In a movie called *Nadia's Journey* co-directed by Nadia Zouaoui and Carmen Garcia, Nadia Zouaoui, now a Canadian living in Montreal, Quebec, visits her homeland, Kabylia, a small village in Algiers. She interviews women in her extended family who tell the story of women's confinement in their homes by fathers, brothers, and husbands. Even by their own fear of what others will say if they venture steps away from the front door "for more than thirty seconds." According to the National Film Board of Canada's website,

> Nadia's Journey exposes the terrible, complex plight of women who have been held captive in their own homes since puberty. Poetic and compassionate, this feature documentary reveals the tribulations of being a woman in a patriarchal culture steeped in strict Muslim tradition and obsessed with virginity. This is a society that keeps women in a state of servitude. The background for the film is Nadia's own story, that of a young woman forced at age 19 to marry a man twice her age, an Algerian living in Montreal who chose her from a photograph.[4]

This poignant documentary presents an example of the power of video images broadcast both on television and the Internet to open the front doors.

[4] Retrieved on March 10, 2008: http://www.nfb.ca/press-room/communique.php?id=15700

> To think about the use of video used in MR-TLRs for educating ourselves and others, one needs to consider not only the affordances of breaking down the doors that confine, but also how to prevent the worst cases from occurring. And to prevent this backlash from occurring, educators may need to consider how digital video texts coupled with constructionist interactive software for knowledge construction will become change agents in educational settings.

The Perspectivity Framework

Instead of focusing on how video can be used to facilitate *critical thinking* (Kamin, O'Sullivan, Deterding, & Younger, 2003, Hilgenberg & Tolone, 2000), *inquiry-based learning* (Edelson, Gordin, & Pea, 1999), or *problem-based learning* (Barrows, 1986; Hmelo-Silver, 2004), we return to the focus used by Goldman-Segall starting in the mid-1980s on how video-based multimedia tools and representations of children's thinking can be experienced as a evolving social environment for sharing perspectives about knowledge and about each other's versions of those understandings. It is also the case that students, teachers, and researchers of all ages make use of visual technologies to share insights and build knowledge upon the relationship between one's personal perspective and others' points of viewing (Goldman-Segall, 1998). The *perspectivity framework* as first proposed by Goldman-Segall and Maxwell (2002) contributes to the evolving transformation currently under way in education as children are now encouraged to use a range of media within learning spaces to construct knowledge (Hmelo-Silver, 2004; Resnick, 1996).

In this chapter, we propose that the perspectivity framework is also an educational framework for learning, teaching, and researching with multimedia presentation. It provides a tool to take advantage of the richness of individual and diverse perspectives as we select, analyze, and construct media, particularly video, on and for iPods, handhelds, and online learning environments. The perspectivity framework has previously been defined as a research approach for making meaning of digital video data by layering multiple points of viewing. The video data become robust as meanings are negotiated, layered, and saturated with implication and significance. The layering can occur with an online video analysis tools, such as Orion™ at <http://www.videoresearch.org> (Goldman, 2007) or other video data selection and analysis systems (Stevens, Cherry, & Fournier, 2002; Pea, Lindgren, & Rosen, 2006). It can occur without technologies, of course, but the technologies act as *tools to think more deeply about the process*.

The Perspectivity Framework:

- Empowers students to share each other's viewpoints.
- Leads to learning as reflection through sharing different viewpoints among the participants.
- Induces a heightened sense of immediacy, social presence, and social networking.

- Creates a community of online social network.
- Enables students, teachers, and researchers to review and change their own perspectives in light of the views of others who may have different strategies and knowledge on the subject.
- Creates more permeable and equitable boundaries between learning, teaching, and researching. Teachers and students are partners. They share each other's viewpoints and acquire knowledge together.

In the following example we are going to discuss two cases, one fictional for a school of the future and the other a real school on Vancouver Island.

Cases

Let us first propose a fictional case for what could happen in a classroom of the future. A group of teacher/s and young people learn about acceleration by creating a range of objects falling to the ground from high places. The teachers and learners are engaged in a common school-wide project. During this project, teachers provide and sometimes hold back their professional know-how, content background, and methods of group investigation to think more deeply, as a group, about mathematical and physical behaviors. Teachers and students use the resources available to them, including online wikipedia-type information sources; they build their own wikis or other shared learning environments or, perhaps, design physical structures out of available materials; and, they do what researchers do – ask questions within a community of practice. From time to time, a person in the group who seems to have a handle on the problem may explain it to others, hold a seminar, give a lecture, and propose exercises for others. This person may become the designated "teacher." In fact, everyone would see herself or himself as the person who can create a convivial learning environment and be responsible for each other's learning, including her or his own. This person would be involved in a discovery of what happens in the acceleration project as well as what makes her or his teaching better by delving into multimedia databanks to understand how acceleration or any other topic was taught in different, perhaps better, ways.

How is this similar from to what occurred in the 1990s at the Bayside Middle School on Vancouver Island when students studied an endangered rainforest across the curriculum? Let me describe this study with a new lens.

At the Bayside Middle School, I (Goldman) worked with school administrators, teachers, grade five and six students, and my research partner, Ted Reicken on a project called The Global Forest. For almost 3 years, we collaboratively investigated an endangered rainforest called Clayoquot Sound on the west coast of Vancouver Island. Although this study has been reported in *Points of Viewing Children's Thinking: A Digital Ethnographer's Journey*, we now reflect back on how learners, teachers, school administrators, and researchers worked collaboratively to investigate an endangered rainforest from every curricular area. While the teachers, students, and the researchers shared the experience of visiting logging sites and rainforests, and also used advanced video technologies to record, edit, and share these records, a learning culture was created and also archived for future teachers, learners, and researchers to apply and reapply. In this study, we all learned from each other by collaboratively creating the learning environment and sharing each other's viewpoints. The research study becomes, as this one is now doing, a living record of new interpretations on records (data) that can easily be revisited through many different frames. Moreover, these visual records of this growth of culture of teaching and learning and the written documents that describe it make possible the spawning of other cultures, much as in social networking. This is the future of MR-TLRs, multimedia records/representations of teaching, learning, and research – longevity of data and the spread of cultures.

These cases show how learners, teachers, and researchers in video cultures experienced an enhanced sense of immediacy and agency, and a deeper appreciation of their own perspective and the perspective of others. Moreover, one can clearly see how they learned to appreciate each other's viewpoints, a trait we should all hope children (and adults), as global citizens, may learn as they try to work together in every walk of life. These studies indicate that the interwoven learning cultures are on the edge of a major shift as more and more knowledge construction is "related to" the selection, interpretation, and construction of knowledge using these multimedia interventions in a collaborative way. It is not a revolution that we see. Not how Lev Manovich (2001) describes the continuity of media forms, but rather an evolution of overlapping genres, each interacting with the other as we move from stone carvings to virtual video-based game worlds for exploration and connoisseurship.

Donald Schön once wrote about the importance of reflection in learning (Schön, 1983). We will argue that thoughtful use of multimedia representations by learners, teachers, and researchers will lead to learning as reflection (Suchman & Tngg, 1991; Hansen, 1994; Moon, 1999). Is there a heightened sense of immediacy, social presence, and social networking? Does this learning expand the possibility of reviewing events that can lead to creating a generation of epistemologists? In short, do multimedia representations provide learners, teachers, and researchers with a powerful method of reflecting upon and negotiating meaning within a culturally diverse social network.

POV-ing Meets MR-TLRs in the Twenty-First Century

Our vision for the future is that learners, teachers, and researchers in distributed communities will gain knowledge and tolerance of diverse ways of living through learning about each other. It strikes us as not an accident that the word *vision* is about seeing – our vision, and that the word *theoria* once meant "a viewing" in Latin. In creating a shared vision for educational change, we build upon existing educational genres and create even more compelling digital video re/presentations and multimedia representations, thereby providing valuable insights into the range of possibilities in the learning process that is infused with teaching others and conducting research, no matter what age a person is or position she holds.

As participating members of social networked cultures, our community of researchers, teachers, and learners will gain deeper, richer, and perhaps more valid windows into our own and each other's thinking processes by sharing our roles. And this will change education in ways that we could not have foreseen before the digital video evolution.

One challenge we face, yes, the nightmare, is that governments around the world will shut down shared, interactive, and convivial online spaces before we have the opportunity to create robust international learning webs to support collaboration on serious problems facing our planet in the coming decades. Another concern is that the people who violate others will cause windows, doors, and gates to close and welcome back the gatekeepers. A third problem will be if standards will be established that prevent the next generation of learners, teachers, and researchers from working collaboratively to grow new kinds of learning cultures as a community. If achievement standards continue to dictate to teachers what learners must know, the cycle of containment within repressive institutional educational regimes will perpetuate. And, sadly, we will miss the most fertile time for change that the educational system has experienced in a century.

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Creating Shared Visions of the Future for K-12 Education: A Systemic Transformation Process for a Learner-Centered Paradigm

Charles M. Reigeluth, Alison Carr-Chellman, Brian Beabout, and William Watson

Abstract This chapter compares a number of systemic change approaches to K-12 school innovation. The approaches reviewed in this chapter range from idealized design to leveraged emergent design, school-wide to district-wide transformation, and key-leader directed to broad-stakeholder-directed transformation. Definitions of each approach are reviewed, along with key practices of each and comparisons among them. The chapter does not recommend a particular approach for all or even most cases, but rather is intended to stimulate discussion and understanding of their advantages and disadvantages within the culture and context of any particular school community.

Keywords K-12 · Learner-centered · Instructional design · Idealized design · Leveraged emergent design · School-wide transformation · District-wide transformation · Key-leader directed transformation · Broad-stakeholder directed transformation · Systems design · Principles of participation · Continuity and holism · Disruptive technology · Systemic change · Instructional technology

Introduction

This chapter presents a variety of alternative approaches to the process of helping K-12 school districts to transform themselves from the industrial-age paradigm of education to a learner-centered, information-age paradigm. The purpose of the chapter is to generate discussion about the pros and cons of each alternative. While the approaches are presented in dyads, this oversimplifies the complexity of the alternatives available to school change participants as they try

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to determine which approach or combination of approaches is best for their situation. We do not think that choices are typically dichotomous or that these represent the entire array of possible choices. Rather this structure helps to bring into relief and clarity the differences between some of the most important alternatives we have encountered.

The chapter begins with a look at idealized design as compared to leveraged emergent design, followed by an examination of school-wide versus district-wide transformation, followed by key-leader directed change versus broad-stakeholder directed change. Each pair of approaches is defined, the key practices are identified, and a comparison between the two options is discussed. We hope that this chapter will generate lively discussion about alternative approaches to systemic change and will indicate productive avenues for future research.

Idealized Design Versus Leveraged Emergent Design

The primary approach offered in the literature is the idealized design approach pioneered by Ackoff in the corporate sector and adapted by Banathy to the K-12 education context. This is discussed next, followed by the leveraged emergent design approach – a newly developed alternative (Reigeluth, 2006).

Idealized Design

Definitions

Those adhering to an idealized design approach to the creation of educational systems focus on the creation of a "guiding image" (Banathy, 1992, p. 178) that is created by the designers as they attempt to breakfree from the traditions, assumptions, and inertia of current schooling practices in creating more effective systems of education. Ackoff (1979) refers to idealized design as "a design of the system with which the designers would replace the existing system *now* if they were free to do so" (p. 191). There is a palpable "stopping of time" as designers and stakeholders remove themselves from the day-to-day operations of the system and spend time focused entirely on dreaming up the ideal system. Thus, idealized design is a design process initiated by creating a "picture" of what the system would look like in a perfect world.

Nelson and Stolterman use the term *desiderata* to explain "the original expression of what is desired" (2003, p. 48). These desires differ from what many refer to as a *vision* in that desiderata are temporary, fuzzy gut-feelings of the way things could be which are refined throughout the design process. This stands in contrast to a *vision* which, once created, remains a fixed point toward which the change is directed. So we could redefine idealized design as a design process initiated by articulating a "desiderata" of what the system would look like in a perfect world.

How it Works

Nelson and Stolterman describe design as "the ability to imagine *that-which-does-not-yet-exist*" (Nelson & Stolterman, 2003, p. 10). There is a conscious letting go of the particular realities which may have led to the initiation of the design process and a focus on the ideal. Nelson and Stolterman's term *parti,* defined as an "explosive appearance of an… encoded solution to a complex design challenge" (p. 212), is a result of engagement with the design process. The *parti* is the new, creative breakthrough that propels the design process forward. The *parti*, informed by the desiderata, serves as the seed for the entire design effort and may come from anywhere in the organizational hierarchy. The creation of this "seed" becomes the most important part of the idealized design experience.

Work in idealized design comes primarily out of the operations research work in the business sector pioneered by Russell Ackoff. He sought a proactive design paradigm that would create organizations based on participation, continuity, and holism (Ackoff, 1979). The *principle of participation* posits the idea that the planning *process* is more valuable than any plans for action that might come out of it. Thus, a broad base of stakeholders should be involved in planning for change. The *principle of continuity* states that planning and implementation should not be seen as serial processes, but should proceed continuously in parallel, each informing the other. Finally, the *principle of holism* concludes that: "all units at the same level of an organization should be planned for simultaneously and interdependently" (Ackoff, 1979, p.190). Those that plan change in a way that does not abide by this principle run the risk of implementing change that is rejected by certain parts of the system. This proactive design approach has been adopted by practitioners and researchers in a number of organizational contexts (Carroll, 2000; Omerod, 1995; Pourdehnad & Hebb, 2002). Ackoff's groundwork in organizational planning, focusing on stakeholder inclusion, constant searching for improvements, and recognizing important interdependencies set the stage for Banathy to apply these ideas to the design of education systems.

Banathy (1991) recognized that society has undergone a dramatic paradigm shift, leaving our educational system out of synch with the needs and wishes of society. He calls for a *systems design approach* that will realign our lagging educational system with the constantly changing society of which it is a part. In true idealized design fashion, Banathy explains:

> We should "jump out from the system," explore educational change and renewal from the larger vistas of the transformed society and envision a new design. Starting design from the perspectives of the overall societal context, we extend our horizon and develop the LARGEST POSSIBLE PICTURE of education within the LARGEST POSSIBLE SOCIETAL CONTEXT (1991, p. 15).

Starting with society as a whole frees the designers from the inertia of the current system and allows them to create a functioning system that is unlikely to be rejected upon implementation. This design process begins with an idealized *image* and moves through a series of iterative stages for elaborating that image to progressively greater levels of detail and clarity, and then to implementation and institutionalization of the new design. Extensions of Banathy's work in the realm of education have been numerous (Carr, 1996; Joseph, 2003; Reigeluth, 1993; Squire, 1999).

Idealized design lends itself to certain types of design settings as opposed to others. It requires an unwavering commitment to the change process, as participants must be trained and continuously supported in their new roles as change agents (Borko, Wolf, Simone, & Uchiyama, 2003). This requires a commitment of both financial resources and time. Volatile organizations undergoing high leadership turnover (Corcoran & Lawrence, 2003), those undergoing extreme changes in the number or type of clients (Arriaza, 2004), and organizations uncertain of the need for change (Fullan, 2000) are not likely to succeed with any type of change, let alone this rigorous model. This is not to say that the need for change cannot be developed and shared amongst stakeholders, but all participants in the process must be willing to work together in good faith if consensus and commitment are to be developed (Reigeluth, 2006). Those organizations able to successfully implement idealized design are first able to generate a strong commitment from all stakeholder groups to both the organization and the process itself.

Ackoff (1979) outlines a five-step process for carrying out idealized design in an organizational context. His first step, *formulating the mess*, involves a holistic, systemic look at the organization and its environment. Second, *means-ends planning*, involves creating an idealized vision of the future and determining what changes are necessary in the current system to move it toward that vision. Third, *resource planning*, determines how facilities, people, money, information, and other resources can be best utilized to meet the vision. Fourth, *organizational and management planning* determines what structures need to be in place for proper executive functioning of the system and for effective organizational learning. Fifth and last, *design of implementation and control* determines who will carry out what tasks in the change process and what the standards of quality implementation will be. This process is similar to Banathy's (1996) four-design spirals: formulating the core definition, developing specifications, selecting functions, and designing the enabling systems. While Ackoff's five-step process of idealized design begins with a close look at the present organization and its environment before moving to the creation of an idealized vision of the future, Banathy's model begins with an idealized vision and then proceeds to develop specific functions to bring the ideal system into being. While they start in different places, both Ackoff (1979) and Banathy (1996) emphasize iteration, a systems perspective, establishing a shared vision, and managing the process of meeting that vision. These practices differ considerably from the practice of leveraged emergent design, to which we turn next.

Leveraged Emergent Design

Definitions

An alternative to (or adaptation of) the idealized design approach is the leveraged emergent design approach developed by Reigeluth (2006) in a systemic transformation effort in Indianapolis. It is based on the following principles.

Leverage. In transforming an existing system to a new paradigm, it is hard to change everything at once. When you change one part of the system, it becomes incompatible with the rest of the system, which then works to change it back. Therefore, you must first change a part or parts of the system that can exert powerful leverage on the remaining parts of the old system – to overcome the force that the old system will exert to push the new parts back to what they were. Starting with a few high-leverage changes can make the whole systemic change process considerably quicker and easier. (Note that this is not piecemeal change even though you start by changing a small number of high-leverage pieces, because the changes will, if done right, result in a different paradigm of education, just as if the idealized design approach had been used.)

Visible progress. It is important for participants in a systemic change process to be able to see progress often. This sustains motivation and wins over skeptics.

Emergent design. It is difficult to design such a complex new system from scratch, for it is difficult to predict what will work best. In an emergent approach, a few guiding principles or beliefs ("strange attractors" in Chaos Theory or "desiderata" in Nelson & Stolterman's work) are selected, then a few high-leverage changes that are consistent with the guiding beliefs are implemented, and finally the remaining changes occur through creativity, trial, and error – they gradually emerge over time.

Transcending traditional mindsets. A different paradigm requires a different worldview. Helping stakeholders transcend their traditional mental models or mindsets about education is critical to a systemic change process. Failure to transcend causes resistance, or at best an inability to implement the new system, due to a lack of understanding.

Ideal seeking. As in Ackoff's idealized design approach, thinking in the ideal helps participants to transcend the mental model of the current paradigm and imagine something potentially far superior. This makes it most valuable to use at the beginning of the change process, while preparing what Ackoff calls a "rough sketch" of the new system. That rough sketch is the guiding beliefs (which serve as "strange attractors"). To allow the principles of leverage and emergence to play out, the idealized design should end when the rough sketch is completed, after the participants have transcended their traditional mental models about education.

Broad-Stakeholder Ownership. Given the importance of transcending traditional mindsets, it is essential to have broad participation in the change process, so that a sufficient number of stakeholder mindsets support the systemic change. However, to develop true commitment to the new shared vision (represented by the guiding beliefs) and thereby minimize resistance, participants must go beyond participation to a sense of ownership of the new vision. Ownership is developed by encouraging participants to revise the vision (ideal beliefs), which ties in with the principle of emergence.

Consensus Building. Broad ownership can't happen without a consensus-building process, because participants begin with very different beliefs about what an ideal educational system would be like. The consensus-building process helps participants to understand others' perspectives and thereby evolve their mental models to a set of shared beliefs.

How it Works

Here is a tentative process for using the leveraged emergent design approach:

1. Develop district-wide ideal beliefs. A district Leadership Team is formed of about 25 opinion leaders in all stakeholder groups to develop a set of ideal beliefs for the entire school district, with broad-stakeholder involvement.

2. Develop district strategy and support capacity. The district Leadership Team develops a broad strategy for the systemic transformation process. Primarily, this entails deciding how much of the district to transform at once: all "feeder systems" (a feeder system is all schools that feed into a single high school) or just one; all grade levels in a feeder system or begin with, say, K-3 and move up one grade level per year; all schools in the feeder system or just a few, and so forth. This decision is influenced by the amount of district and external resources to support those who are transforming, and it should be made with broad-stakeholder ownership in a consensus-building process. In addition, a Central Support Team is formed in the Central Office, to support the formation and operation of building-level design teams.

3. Create building-level design teams and strategy. A School Design Team is formed in each building with broad-stakeholder involvement. Each Design Team's first task is to decide, again with broad-stakeholder involvement, on a building-level strategy for the systemic transformation process. Primarily, this entails deciding how much of the school to transform at once. If it is a large school, they may decide to form several small schools or learning communities within the building, and they may decide to start with just one or all of them. This decision depends primarily on school size, teacher cohesion, and mindsets.

4. Elaborate the beliefs. One School Design Team is formed for each "new" school to be designed in each building with broad-stakeholder involvement. Each Design Team elaborates the district-wide ideal beliefs in such a way as to tailor them to their school and neighborhood and develop broad-stakeholder ownership of them. These will serve as "strange attractors." Duffy, Rogerson & Blick (2000) also recommend that a *district-level design team* be formed because the "core work process" should be viewed as the P-12 process, not a P-6 process, a 7–8 process, and a 9–12 process. This helps ensure systemic coherence.

5. Decide on high-leverage, structural changes. The Central Support Team helps each School Design Team to reach broad-stakeholder consensus (mindset change) on a few high-leverage, structural changes that will implement the guiding beliefs for systemic transformation to a learner-centered paradigm. Sample high-leverage, structural changes are offered to help participants understand what they are, and different schools might choose different structural changes that they believe will be more consistent with their beliefs or will provide more leverage in their school. Samples might include

- replacing the current report card with an inventory of attainments whereby each student must reach a standard of attainment before progressing to the next attainment,
- requiring a personal learning plan (or IEP) for every student whereby each student can immediately progress to the next attainment that is appropriate for him or her upon mastering the current one,
- requiring a change in the teacher's role to a coach or facilitator, and
- requiring active parent participation in setting and attaining their student's goals.

This phase is the heart of the leveraged emergent design approach, so the following is some additional guidance for conducting it.

5.1. **Elaborate the ideal beliefs.** Design teams engage their stakeholders in discussions of the district-wide ideal beliefs to build a deeper understanding of them and to develop a more detailed set of ideal beliefs tailored to their educational level, but compatible with the district-wide beliefs. Discussions of learner-centered instruction are also important to this task.

5.2. **Understand high-leverage, structural changes.** Design Teams engage their stakeholders in discussions of the high-leverage, initial changes listed above as ways to understand what they are.

5.3. **Decide on initial changes.** Design Teams engage their stakeholders in reaching broad-stakeholder consensus on whatever initial changes they believe will best serve the high-leverage function for their elaborated ideal beliefs. Mindset change and consensus-building are paramount here.

- Different schools will require different amounts of time to reach broad consensus on their ideal beliefs and initial changes.
- The consensus must be very broad among all the school's stakeholder groups, and it must be true consensus, not acquiescence.
- A Design Team could, of course, plan and implement more changes at the same time, to support those changes, such as students having the same teacher for 3 or 4 years and changing classrooms into multiage, non-graded learning environments. However, they must avoid the temptation to plan out the new system in detail, because that is very time-consuming.

The high-leverage, structural changes are the vehicles for change and sources of leverage. They provide sufficient sustainability and leverage to gradually change all other aspects of the old system to be compatible with the new paradigm. There is no detailed ideal design for each building to develop and implement. This is a truly emergent approach, with the guiding beliefs serving as "strange attractors" to guide the emergence.

6. Plan the means. The means planning stage is very similar to Ackoff's counterpart in the idealized design approach. Once broad consensus has been reached on its high-leverage initial changes, each design team identifies and procures, with help from the Central Support Team, appropriate instructional methods, practices, and tools for implementing all of its initial, high-leverage, structural changes. Task forces may be created to accomplish particular tasks, such as developing their inventory of attainments. Some task forces may be jointly formed by more than one Design Team. Task forces receive considerable support from the Central Service Center. The Design Teams provide professional development experiences for their staff to develop their competence in using those methods, practices, and tools. They procure and install equipment and remodel facilities as needed. External funding is important for being able to "retool" their school.

7. Implement the initial changes. The methods, practices, and tools are implemented for all the initial, high-leverage, structural changes. Professional learning communities are formed to help members implement and improve the initial changes and any other changes that may be found helpful to support those initial changes. Formative evaluation and revision are continuous.

Comparison

In this section we discuss advantages for each of the two approaches and explore some comparisons between these two alternatives. As we've pointed out earlier in this chapter, it is certainly not the case that we wish to engage in dichotomous thinking, rather we see these two as viable options on a continuum from a process in which the new system is completely designed in great detail before any changes are made, to a process in which the new system is only partially designed before any changes are actually made.

Pros for the leveraged emergent design approach. Some of the advantages of this approach over the idealized design approach include

- There is a much lighter up-front investment of time and resources in designing implementable changes for each building, reducing expenses and allowing more schools to proceed at the same time.
- Stakeholders don't need to reach consensus on every aspect of the design before implementation – just the few high-leverage initial changes – so it is easier to reach broad consensus.
- Early implementation of the initial changes may help skeptics to see the value and workability of the changes.
- Significant changes are implemented sooner than with the idealized design approach, serving students sooner, as well as helping to maintain participant motivation.

Pros for the idealized design approach. Some of the advantages of this approach over the leveraged emergent design approach include

- It avoids the risk of a poor choice of initial changes (insufficiently structural) resulting in only piecemeal changes.
- It avoids the risk of a poor choice of initial changes (insufficient leverage) resulting in the old system forcing the changes to be undone.
- It is likely to be less uncertain and chaotic.
- There is a greater likelihood that all participants will share a clear, common vision of the new system.

Whichever approach is used, it is essential to continue to work and think systemically. Without clear communication and permeable boundaries between systems, any set of changes will be likely to fail. Instead, leveraged emergent design or idealized design must take place within a systemic view, keeping in mind the essential tenets of systems thinking and systems theory.

School-Wide Versus District-Wide Transformation

Banathy (1996) notes that systems exist solely in the mind as a way of assigning meaning to an entity or phenomenon. Two popular ways to define the system-to-be-changed in educational reform are the school and the school district (Squire & Reigeluth, 2000), and each represents a different approach to systemic change. School-wide transformation is discussed next, followed by district-wide transformation.

School-Wide Transformation

Definitions

Those adhering to a school-wide transformation approach to systemic change define the system of interest as the school. Several different terms are used to describe this approach, including whole-school reform, site-based or school-based reform, and most commonly, comprehensive school reform (CSR).

School-wide transformation is a broad approach that covers a diverse number of change processes and designs. While these designs differ in their focus, they share characteristics, the foremost being a comprehensive transformation of the individual school. The designs also share a focus on helping all students achieve high-academic standards, the application of research on best practices, the involvement of parents and community members in schools, professional development of teachers and administrators, and the creation of a shared vision across faculty and community (McChesney, 1998).

Borman, Hewes, Overman, and Brown (2002) state that CSR is defined by the U.S. Department of Education using 11 components that not only cover these previous characteristics but also include a focus on using designs that have been scientifically shown to significantly improve student academic achievement, identifying resources for sustaining the change effort, incorporating assistance from an expert entity in school reform (for example, an institute of higher education), and implementing yearly assessments of the change effort.

How it Works

Most systemic reform implementations in the past 20 years have utilized the school-wide approach. Many of these implementations were funded by one of two programs: New American Schools (NAS) and the Comprehensive School Reform Program (CSRP), and CSRP tends to focus on established reform model designs and the processes for implementing them.

NAS

NAS was formed by the first Bush administration in 1991, raising private funds to support design teams which were to develop "break the mold" whole-school designs. Eleven initial design teams were awarded funds, and NASs first-phased implementation of the designs concluded in 1998, with design teams having partnered with more than 550 schools by 1995, including ATLAS, Co-nect Schools, Expeditionary Learning Outward Bound (ELOB), Modern Red Schoolhouse (MRS), and America's Choice Design Network (ACDN; originally National Alliance for Restructuring Education), and Success for All/Roots & Wings (SA) (Berends, Bodilly & Kirby, 2002). The implementation of design models was conducted by schools partnering with a specific design team, which assisted in the implementation of the model.

The different design models focus primarily on what the new schools should be like, so their change process approaches are primarily implementation approaches, rather than design approaches, although some room for adaptation of their designs is often allowed. While the implementation approaches of the five different design models listed above do vary considerably, three of them focus on faculty professional development and teamwork (ATLAS, ELOB, ACDN).

After initial feedback of schools struggling to reform within unsupportive districts, NAS outlined a scale-up strategy to partner with school districts rather than just schools (Berends et al., 2002). These districts pledged to have 30% of their schools using NAS designs within 3 years and provide support for these schools, with the idea that this would create a stable core of schools within the district that would help to encourage all district schools to reform. This is a small step away from the school-wide approach toward the district-wide approach.

Hatch (2000) reports that results were mixed, with many schools that tried drastic systemic reforms in such districts lagging behind and largely being unsuccessful. NAS had RAND implement several evaluation studies of the schools, which found that reform initiatives were active and influenced policy but that the initial hypothesis that a school could improve its performance by adopting a whole-school design was largely unproved (Berends et al., 2002). Furthermore, the scale-up hypothesis, that a district that reformed 30% of its schools using NAS whole-school approaches would become stable and high performing, was disproved, with districts reverting back to their former status when administrations changed (Berends et al.).

CSRP

CSRP (originally the Comprehensive School Reform Demonstration program) was formed in 1997 when Congress appropriated $150 million to support schools implementing CSR models. It was included as a part of the No Child Left Behind Act, with over 1,800 schools in all 50 states, the District of Columbia, Puerto Rico, and schools funded by the Bureau of Indian Affairs receiving grants as part of the original 1998 cohort. $368 million was appropriated in 2003 for CSRP, and an estimated 3,000 new schools are annually expected to receive funding ("Comprehensive School Reform Program: About Us").

While some schools involved in CSR develop their own reform models, many try to adhere to the CSR guidelines by turning to expert external groups for a pre-designed and researched model and support, including some of the original NAS design teams. Some of the more well-known groups, apart from any of the surviving NAS teams, such as Success for All, include Comer's School Development Program (SDP), focusing on creating schools that support students' health, social, emotional, and academic challenges; Hirsch's Core Knowledge reform (CK), focusing on the establishment of a common core of knowledge for all children; and Sizer's Coalition of Essential Schools (CES), which attempts to create supportive and rich learning environments by adhering to nine broad principles (Borman et al., 2002).

These groups share similar visions, which not only largely adhere to the CSR guidelines, but also are similar in their lack of guidance for the change process. They tend to offer a model and expect it to be implemented.

District-Wide Transformation

Definitions

Those adhering to a district-wide transformation approach to systemic change define the system at the school district level. Schlechty (1990) identifies the school district as the unit for change, emphasizing how school districts often lack a shared vision and necessary supports for change to occur, and therefore, leadership needs to be emphasized within the district. Duffy et al. (2000) emphasize the district even more strongly, stating that limiting change to school-wide reform is a piecemeal approach and is insufficient by itself to produce systemic change. Jenlink, Reigeluth, Carr, & Nelson (1996) advocate district-wide systemic change, saying "that systemic changes require changes beyond the scope of a classroom or a school building; that they require district-level changes as well" (p. 22).

The argument for selecting the district as the focus for change is that school-based change efforts are likely to fail if the schools do not have the support and shared vision of the district. Duffy and colleagues argue that focusing on a megasystem larger than the school district as the unit of change would be too complex and untenable (2000). Therefore, the school district should work with its schools to create a shared vision, while ceding autonomy to them for designing and implementing models that fit the vision (Duffy et al., 2000; Jenlink et al., 1996).

How it Works

There are several processes for implementing systemic change at the district level. Duffy and colleagues' (2000) Knowledge Work Supervision (KWS) process focuses on four phases:

- Building support for innovation
- Redesigning for high performance
- Achieving stability and diffusion
- Sustaining school improvement

and their process identifies five key players:

- A knowledge work coordinator, who serves as an "integrator" who provides tactical leadership
- Cluster improvement teams, which are composed of K-12 inter-connected schools such as a high school and the elementary and middle schools that feed into it
- Site improvement teams, which create new designs for their buildings while considering the relationship to other members of their cluster
- Communities of practice, whether formal or informal, that disseminate their knowledge throughout the system
- A central service center, a redesigned central office which supports teachers and administrators as they pursue their change goals.

Jenlink, Reigeluth, Carr, and Nelson (1998) identify a five-phased approach broken down into 26 discrete events and many continuous events. The phases are as follows:

- Assess readiness and negotiate an agreement
- Prepare core team for change process
- Prepare expanded teams for the process
- Engage in design of new educational system
- Implement and evolve new system

Both of these processes share key characteristics for transforming a school district systemically. These include strong attention to creating a shared vision in the district, involving stakeholders, illustrating the need for change, creating momentum to drive the change process, and giving schools control over their own designs.

While no complete evaluations of district-wide systemic change programs were available, it is worth noting that some of the evaluations of school-wide programs identify the need for a larger, district-wide process. Datnow and Stringfield (2000) reviewed findings from 16 reform projects and more than 300 case studies and found that reform efforts are more likely to be effective when goals and work are shared across design team, school, district and state. Furthermore, the RAND study of NAS findings "dramatically proved" that the district needs to provide a supportive environment for schools to successfully implement change (Berends et al., 2002, p 174). The NAS' scale-up methodology showed their own recognition of the need to shift focus to the district level.

Comparison

Pros for the School-Wide Transformation approach. Some of the advantages of this approach over the district-wide transformation approach include

- Less complexity
- Fewer resources required
- Shorter time frame
- Stronger research base on past implementations and models

Pros for the District-Wide Transformation approach. Some of the advantages of this approach over the school-wide transformation approach include

- Stronger support mechanisms for schools to implement change
- A more systemic view of process
- A shared vision for all stakeholders
- Ongoing commitment to the district as a learning organization

Key-Leader Directed Versus Broad-Stakeholder Directed Transformation

Schlechty (1990) has developed a "marketing approach" to systemic change that is driven principally by a visionary superintendent. This stands in contrast to a user-designer approach that is driven by as broad a range of stakeholders as possible.

Key-Leader Directed Transformation

Definition

"If new structures are to be invented, then educational leaders must be risk takers" (Schlechty, 1990, p.152). In the work of educational reformer Phillip Schlechty, there is a staunch reliance on leadership to initiate change. Leadership can come from any place in the organization, but "ideas begin with individual women and men; they do not begin in groups" (p. 50). According to Schlechty, without the efforts of a visionary leader, most attempts at change are destined to fail.

Schlechty also sees the nearly continuous string of failed school reforms since the 1950s as a result of the "sales approach" to school change:

> Too often, those who try to bring about change approach the task as a sales problem. Just as sales tries to break down market resistance to a new product, leaders of change concentrate on overcoming resistance to change... Marketing change, by contrast, begins from the view that change must satisfy the needs and values of those whose support is essential... It is one thing to get people to tolerate change; it is another to get them to support change with their own time, energy, and creative capabilities (Schlechty, 1990, p. 84).

Educational reformers utilizing Schlechty's "marketing approach" must initially focus on the customers, which in this case are students. By providing students with important school work at which they can be successful, schools can change and remain viable democratic institutions in our information-based society. Proponents of key-leader directed change *set their sights on students and how to make their experience successful*. An important distinction of key-leader directed design is that the suggested change is purposefully altered based on the change agent's understanding of stakeholder values. If the proposed change is predicted to contradict deeply held stakeholder values, then alterations to the change are made to make it more palatable. This approach is flexible in terms of specific changes, but does not explicitly invite stakeholders into the formation of overarching goals.

How it Works

Schlechty (1990) notes three powerful ways in which leaders can increase the chances of successful change: (1) foster and communicate a shared vision, (2) emphasize a results' orientation, and (3) utilize shared decision making.

Schlechty's version of creating a shared vision includes allowing information to spread easily throughout the organization so that bottom-up reforms, which might be more easily implemented due to higher initial support, can reach the leadership rapidly. Obtaining a shared vision might also include strategic marketing in which "the trick is to segment the market so that the values that come into play are taken into account and to group the customers (for analytical purposes) in ways that reflect significant clusterings and emphases on these values" (1990, p. 85). Thus, identifying possible flash points for opposition in advance and addressing them early-on becomes an important part of the marketing approach.

Emphasizing a results' orientation involves evaluating current and future practice in reference to the school's established purpose. Schlechty states that the purpose of a school, when viewed as a knowledge-work organization is "to invent schoolwork (knowledge work) at which students are successful (students can do it and do it) and from which students learn something that is of consequence to those on whose support the school relies" (1990, p. 53). If this purpose is assumed, then evaluating results is simply a matter of evaluating whether or not activities move the school toward this stated purpose.

Utilizing shared decision making is viewed by Schlechty as both an aesthetically pleasing practice in a democratic society as well as a style of leadership that will result in "better decisions and better results" (1990, p. 52). Restructuring management and time so that workers who are low in an organization's hierarchical structure have the opportunity to participate in decision making is believed to result in an organization that is better able to function effectively.

All three of these characteristics go together, and none can be fully implemented without the other two.

Additional work in key-leader directed design has been done by researchers interested in the ways leaders can prepare organizations for change. Latchem and Hanna (2002) apply Schlechty's work to the integration of computers into the classroom. They describe "disruptive technology" (p. 204) as that which responds to customer needs and forces the organization to operate differently. This outgrowth of key-leader directed change maintains a customer focus but is not as reliant on managers as the original. Additionally, scholarly work has focused on teacher leadership as educational change and how leadership development for teachers might serve to improve a school's operation in a context of change (Cox, 1999).

An important distinction of key-leader directed design is that the suggested change is purposefully altered based on the change agents' understanding of stakeholder values. If the proposed change is predicted to contradict deeply held stakeholder values, then alterations to the change are made to make it more palatable.

Broad-Stakeholder Directed Transformation

Definition

User-design is an approach to design that is highly aligned with idealized design and focuses on a very significant, empowered engagement of many stakeholders. It has been defined (Carr-Chellman, 2006) as "*an authentic empowerment of a particular set of stakeholders, the users of any innovation, such that they are creating their own systems of human learning*." User design is founded on systems theories and understandings of the basics of systems such as interconnections and interdependencies. User design as applied to Educational Systems Design (ESD) stems from work done by Banathy (1991), Reigeluth (1993), and Jenlink (1995). All of this earlier work from the 1990s focused on very potent forms of stakeholder participation that went far beyond earlier conceptions of stakeholder participation, such as those of Epstein (1997).

The foundations of user-design are deeply rooted in Human Computer Interface, and particularly the Scandinavian theories surrounding Participatory Design (Schuler & Namioka, 1993). The process of user design is less systematic and linear than traditional instructional design, and therefore has more in common with idealized design processes.

How it Works

The underlying principles of user-design are that the design and decision making need to be a shared activity across as many different stakeholders as possible. In this sort of approach, the users *become* designers, and the professional designer has to offer assistance and education where appropriate with just-in-time learning. This is a dramatic shift in the role of the designer and in the role of the participants/former recipients of innovations. Because of this shift, power has to be carefully considered as a primary variable in the implementation of user-design approaches. In certain contexts, user-design will not be possible because the idea of shared power is simply not compatible with the leadership or the designers.

Despite this possible drawback, in general, we can say that the empirical findings on the engagement of stakeholders in public school change show positive outcomes on both significant and superficial stakeholder participation (e.g., Hafner, 1992; Henry, Dickey, & Areson, 1991; Wang, Haertel, & Walberg, 1995). In addition, engagement of stakeholders in more general social systems design tended to yield positive outcomes (e.g., Brandon, 1999; Greene, 1988; Saegert, 1996). These research findings are encouraging and should help those readers willing to consider such a radical approach.

The basic stages of user-design include readiness, team selection, process/design tool selection, capacity building, process engagement, trials of innovations, iterative assessment of process and products innovations, and evaluation of user-design systemic impacts (Carr-Chellman, 2006). These stages are moved through very loosely and not in any sort of true linear fashion. But in general, some stages will come before others, such that, for example, the readiness of any organization should be at least initially assessed prior to selecting team members or tools. There is a variety of considerations associated with each of these phases, for example, tool selection should be a shared activity, one which is facilitated by the designers but not owned by the designers. The basic process calls for fairly early trials of innovations in somewhat of a rapid prototyping fashion. Further discussion of each phase can be found in Carr-Chellman (2006).

Comparison

The key-leader approach and the user-design approach share some commonalities, particularly as the key-leader approach requires building a shared vision and respects the notion that innovative ideas may come from anywhere within the system. However, there is a fairly large gap where power is concerned. It is clear that power remains with leadership in the case of the key-leader approach, whereas in user-design the decision-making power resides with users themselves. In many cases, the user-design approach may not be appropriate, despite its more aggressive user-engagement, because the context may not be at all friendly to the necessary notions of power redistribution or because the requisite resources in terms of time and people may simply not be available. User-design also requires a certain amount of active engagement and responsibility on the part of all system users, and if a context is not prepared for this, then the user-design approach may not meet the needs of a particular school community.

On the other hand, the key-leader approach needs to have willing followers who will engage in the process under the direction of a key leader, and thus a significant key leader must be present in the context. And presumably, the key leader should be an innovator with good communication skills and a compelling personality. Thus, neither of these approaches may be appropriate for all school cultures. In both cases, readiness is essential.

Conclusion

This chapter described a number of systemic change approaches to K-12 school innovation. The approaches included idealized design versus leveraged emergent design, school-wide versus district-wide transformation, and key-leader directed versus broad-stakeholder directed transformation. Definitions of each approach were reviewed, along with key practices of each and comparisons among them. Hopefully, this material will stimulate discussion and understanding of their advantages and disadvantages within the culture and context of any particular school community, and will help identify productive avenues for future research.

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Technology as a Change Agent in the Classroom

Gary R. Morrison, Steven M. Ross and Deborah L. Lowther

Abstract The focus of this chapter is the results of a 3-year implementation of a one-on-one laptop program in a Midwestern school district. Using a mixed methods quasi-experimental design including classroom observations; perception data from students, teachers, and parents; and achievement scores from state-mandated and supplementary assessments of writing and problem-solving, we found that a technological innovation can serve as a change agent in making learning more problem-based and constructivist in nature. Further, the combination of the student "owned" laptops and the transformed classroom environment resulted in sustained gains in writing and problem-solving relative to comparison students. Implications for practice and research in technology integration are drawn from the results.

Keywords K-12 · Change agent · Laptop classrooms · Laptop teachers · Innovation · Teacher use of technology · Technology integration · Achievement · Technology accessibility · Problem-solving · Teacher perceptions about technology · Project-based learning

Technology has long been viewed as a means to deliver instruction since the lantern slide projector was introduced into the classroom in the late 1800s. This conception of technology has guided its use through the last century with the introduction of the overhead projector, 16 mm film projector, television, and

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Data for this chapter are based on a 3-year study conducted by the authors and reported in the annual evaluation reports accessible at http://www.nteq.com/?p = research. Data from the third year were reported in Lowther, D. L., Ross, S. M., & Morrison, G. R. (2003). The Laptop Classroom: The Effect on Instruction and Achievement. *Educational Technology, Research, and Development, 51,* 23–44. This chapter is Presented at Voices of the Past-Visions of the future: Learning and Instructional Technologies for the 21st Century, June 22–25, 2006 Bloomington, Indiana.

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more recently microcomputers and PDAs in the K-12 classroom. The U.S. Congress added support to this approach with the passage of the National Defense Education Act as a reaction to Sputnik in 1957 that resulted in the placement of overhead projectors in many K-12 classrooms to improve instruction. While Clark's (1983) research suggests that technology as a mere delivery device does not enhance learning (separate from the associated instructional strategies), school districts continue to purchase additional technology and new technologies to improve student achievement with little if any documented return on the investment.

While many researchers agree with Clark and have abandoned the media comparison research agenda to identify learning gains attributable to technology, a question still remains as to what effects technology might have on instruction and the classroom environment. In this chapter, we will examine how a technological innovation affected changes in the instruction and the classroom environment that subsequently resulted in improved student achievement and performance.

Background

A Midwestern, suburban school district made a decision during the 1998–1999 school year to implement a laptop classrooms in the fifth and sixth grades in the following year. During this initial year of implementation, parents leased a laptop from a school approved vendor (after the first year, parents purchased laptops from vendors of their choice). Families who wanted to participate in the project, but could not afford to lease a laptop, were assisted by the district's foundation. Once approximately 25 students in a grade level in a school made a commitment to lease/purchase a laptop, a laptop classroom was created. Participation in the program was voluntary. A student in the laptop project attended classes in the four content areas (i.e., math, science, language arts, and social studies) exclusively with other laptop students. The district developed each school's infrastructure to include wireless Internet access and networked printers.

The research team became involved in the project during the planning year and helped the school plan the implementation and evaluation of the project. Specifically, the district decided to implement the Integrating Technology for Inquiry (NTeQ) model (Morrison & Lowther, 2005) as the approach for integrating the laptops. For this chapter, we are defining the technology innovation as consisting of two components – (a) introduction of laptop computers to the class and (b) the teacher training in how to integrate the technology into the classroom. The following is a brief description of the activities related to the implementation of the project.

Year 1

Training for the project started with the distribution of the leased laptops in early July. Teachers participating in the project, "laptop teachers," also received a laptop from the district that was identical to those used by the students. Parents were encouraged to attend one or more evening training sessions on the operating system and Microsoft Office that were taught by the laptop teachers.

The laptop teachers attended 10 days of training focused on the NTeQ model during early July. The NTeQ model uses a problem-based learning approach to integrate computer technology as a tool rather than as a delivery system. A ten-step model is used to develop the problem-based lesson (see Fig. 1). During the training sessions, teachers learned how to develop integrated lessons using the model. Each teacher was expected to develop at least two integrated units of instruction to be used during the school year. The teachers were also encouraged to work as a team and develop a unit of instruction that would integrate the laptop technology in two or more of the core content areas that the teachers could team teach.

During the school year, the lead author of this chapter conducted six, 1-hour support sessions for the laptop teachers. These sessions primarily focused questions and answer sessions with the teachers working together to solve implementation problems. Additional information sessions were held periodically for parents of students in the laptop classes.

Year 2

During the spring of the first year, a second NTeQ training program was held for teachers wishing to participate in some aspect of the program in the second year. This training was offered twice a week after school and was equivalent to a

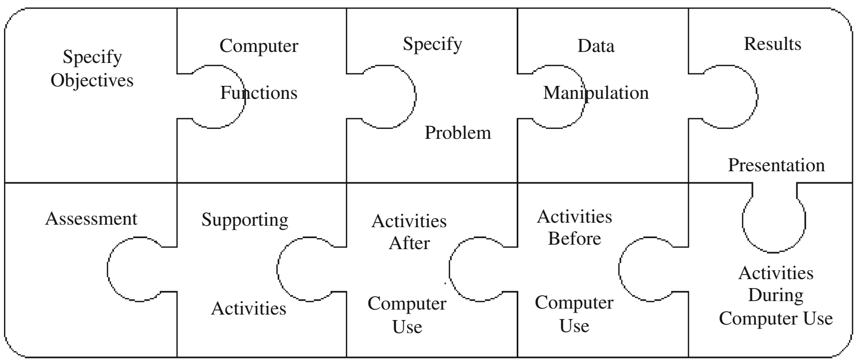

Fig. 1 NTeQ model

3-hour graduate course. Content for this course was expanded to develop additional units of instruction and approaches to utilizing the Internet into the classroom. A similar workshop was conducted during the summer with the first year's laptop teachers serving as coaches.

In the second year, the previous year's laptop students were promoted to the sixth- and seventh-grade laptop classrooms. New students entered the project at the fifth grade and additional sixth- and seventh-grade laptop classrooms were created when 25 students in a school opted to participate.

Based on the success of the first year's implementation, a new classroom configuration was tested. Teachers who had attended an NTeQ training session could opt for 4–6 desktop computers to be placed in their classroom to allow them to implement the NTeQ model. These computers had Internet access and access to a networked printer placed in the room. These computer-enhanced (CE) classrooms provided a comparison for the laptop classrooms for the Year 2 evaluation.

During the school year, the lead author met approximately four times with the laptop and CE classroom teachers to address issues and solve problems. Similarly, occasional meetings were held with parents to answer questions about the project.

Year 3

In the third year, the district provided laptop carts for extended times to participating classrooms. The laptop carts afforded the additional advantage of providing each student with a computer rather than sharing one during the class time. Teacher training for new teachers in the third year was conducted during the summer by experienced laptop teachers. Support during the year was provided by the more experienced teachers. One of the lead teachers from Year 1 was promoted to a position in the central administrative office to provide teacher training and support throughout the year.

Research Design

The research in the first and second years was guided by three research questions. First, is teaching different in a laptop classroom? That is, do teachers use different methods in the laptop classrooms as compared to traditional or CE classrooms? Second, do students achieve differently in a laptop classroom? Are there changes in the classroom environment that will influence student achievement as the result of the introduction of this technology innovation? Third, do students behave differently in a laptop classroom? In a classroom where each student has 24/7 access to a laptop computer and wireless Internet access in the school, is there a change in student behavior due to the technology innovation?

The focus of the research in the third year was on just the fifth-grade students and comparing the laptop classrooms to classrooms with extended access to laptop carts. Six questions guided this research.

- What differences emerge in teaching strategies used during a computer-supported lesson in laptop versus cart classrooms?
- Do laptop students differ from cart students in their writing skills?

Do laptop students differ from cart students in their approach to problem solving?

- Do laptop students differ from cart students in their mathematics, science, and social studies achievement at the fifth-grade level?
- How do students perceive the use and access of laptop computers?
- What do teachers perceive as the benefits and problems of integrating technology in laptop versus cart classrooms?

Data Collection

The data set for the evaluation included classroom observations, student writing test scores, student surveys and focus groups, teacher surveys and interviews, and parent surveys and interviews. Three separate observation measures were used to collect data: The *School Observation Measure* (*SOM*©), the *Survey of Computer Use* (*SCU*©), and the *Rubric for Student-Centered Activities* (*RSCA* ©). The *SOM* examines frequency with which 24 instructional strategies were used during the observations (Ross, Smith, & Alberg, 1999). A companion instrument to *SOM*, the *SCU* was designed to capture exclusively student access to, ability with, and use of computers rather than teacher use of technology (Lowther & Ross, 2001). The *SOM* and *SCU* were based on 60 continuous minutes of observation, divided into approximately 4, 15-minute segments. These four observation periods were then summarized on one *SOM* and one SCU Data Summary forms. The *RSCA* was developed as an extension to SOM and SCU (Lowther & Ross, 2000) to more closely evaluate the degree of learner engagement in seven selected areas considered fundamental to the goal of increasing student-centered learning activities (cooperative learning, project-based learning, higher-level questioning, experiential/hands-on learning, student independent inquiry/research, student discussion, and students as producers of knowledge using technology). Each item includes a two-part rating scale. The first is a four-point scale, with 1 indicating a very low level of application, and 4 representing a high level of application. The second is a Yes/No option to the question: "Was technology used?" with space provided to write a brief description of the technology used. One RSCA form was completed per class observation.

The District's *Writing Scoring Guide* was used to assess prompted writing samples from laptop and control students. At the end of each school year, students wrote a letter of introduction to next year's teacher. These letters were collected and scored with the rubric. Experienced reviewers used the district's four-point rubric (ranging from 1 to 4, with 4 being the highest rating possible) to conduct a blind assessment of the writing samples for Ideas and Content, Organization and Form, Style, and Conventions, yielding four scores per student.

The questions for the student, teacher, and parent surveys, interviews, and focus groups focused on three areas: (a) the impact of laptop computers on increasing personal skills (research, computer, and learning); (b) the impact of laptops on what happens in the classroom; and (c) the benefits, difficulties, and suggested improvements of the laptop program.

In the second and third year, a researcher designed problem-solving instrument was developed with input from participating teachers. This instrument presented students with a problem at a local park where soda pop cans were not being recycled (there was a $0.10 refundable deposit on every can). The students explained in writing how they would approach solving the problem. The solutions were evaluated with a problem-solving rubric consisting of "Understands problem," "Identifies what is known about the problem," "Identifies what needs to be known to solve the problem," "Determines how the data need to be manipulated to solve the problem," "Describes use of technology," "Describes how to present findings," and "Collaborative learning."

In the third year, student achievement was assessed with scores from the district-administered test to measure the following Michigan Curriculum Standards and Benchmarks: mathematics, science, and social studies. The students' fourth-grade (pre-laptop) MEAP mathematics total raw scores from 2001 to 2002 were used as a covariate to control for initial differences among students when making program comparisons.

Results

In this chapter, we are focusing on how the instructional environments differ between the laptop classrooms and the traditional and CE classrooms. The full evaluation reports for each year that report all the data can be found in the NTeQ website (www.nteq.com) and provide detailed analysis and discussion of the achievement measures. The following is a brief summary of the findings.

Year 1

In Year 1 (1999–2000 school year), the fifth- and sixth-grade laptop classrooms were compared to a control group consisting of traditional classrooms that had fewer than five computers in the classroom. The laptop teachers had completed a summer workshop in using the NTeQ model and had varying degrees of proficiency using Microsoft Office and navigating the Internet.

Achievement Scores

A writing sample of 32 laptop students and 32 control students were blindly evaluated by experienced teachers using the district's writing rubric. Mean performance scores for laptop and control students were analyzed via a one-way multivariate analysis of variance (MANOVA) with the four dimension scores serving as the dependent variables. The MANOVA yielded a significant program effect ($p = 0.048$), therefore, univariate analysis of variance (ANOVA) was performed separately on each dimension. All four tests were highly significant and indicative of higher performance by laptop than control students. Effect sizes ranged from $+0.61$ to $+0.78$, suggesting strong and educationally important effects.

Classroom Observations

Of particular interest in this chapter are the assessments of the classroom environment. The researchers completed a total of 32 laptop and 18 traditional-classroom observations. The analysis revealed significant differences, which favored laptop over the control teachers on project-based learning (65 vs. 22% observed), independent inquiry/research (58 vs. 24%), computer for instructional delivery (22 vs. 0%), and computer as a learning tool (88 vs. 17%). In general, strategies promoting learner activity, such as cooperative learning, inquiry, sustained writing, and computer uses were more likely to be observed in laptop classrooms.

There were seven comparisons that yielded statistically significant differences, all of which had associated effect sizes of 0.59 or higher in absolute value favoring the laptop classes: computer as a learning tool ($ES = +2.29$), project-based learning ($ES = +0.95$), independent inquiry ($ES = +0.89$), higher-level instructional feedback ($ES = +0.61$), teacher as facilitator ($ES = +0.64$), cooperative learning ($ES = +0.59$), and computer for instructional delivery ($ES = +0.59$).

Surveys, Interviews, and Focus Group Data

The laptop-student survey responses ($n = 397$), indicated that students felt their computer skills had increased, and they were better able to do Internet research. They were less certain that using computers at school increased their interest in learning, made them want to get better grades, improved their writing, or made it easier for them to work with other students. Over half of the students reported fairly regular use of the laptop and the Internet for completing homework, while even more reported uses for "other things." The researchers conducted six-student focus groups that involved a total of 58 students. Results from the focus groups closely aligned with findings from the student survey.

Thirteen laptop teachers responded to the Teacher Survey. Results indicated that teachers were extremely positive regarding the benefits of the laptop program for them and their students. All agreed that the program experience (a) increased their basic skills in computer applications, (b) increased the emphasis on higher-order learning in their classroom, (c) increased project-based learning, and (d) was beneficial to them as teachers. There was also strong agreement that: they were better prepared to create lessons integrating computers, they frequently integrated technology, their school-related interactions with students and parents increased, and they would like to participate in the project again next year. Seven randomly selected laptop teachers were interviewed. Teachers indicated that due to the laptops, their classroom practices featured more frequent uses of cooperative learning, projects-based learning, and coaching. Teachers reported that laptop compared to non-laptop projects involved more integration of subjects, research, higher-levels of learning, and writing, and the use of spreadsheets, word processing, and the Internet.

Parents ($n = 187$) generally viewed the laptop program as helpful to their children's education. More than half felt that the program *increased* their child's interest in school, involvement in project-type school work, and research skills. Between one-third and one-half believed that increases occurred in school achievement, writing skills, and ability to work with other students. On open-ended items, over one-half of the parents stated that the most beneficial part of the laptop program was that their child had improved his/her knowledge in different subject areas and also improved in computer literacy. The parent interviews were conducted with a random selection of 40 parents (20 in fifth grade, 20 in sixth grade) whose children were participating in the laptop study. Overall, the parents were supportive of the laptop program and felt that it has had a positive impact on the child's learning and participation in school.

Year 2

In Year 2 (2000–2001) of the study, the laptop classrooms were compared to CE classrooms that had 4–6 networked desktop computers. Both groups of teachers had received training in integrating technology using the NTeQ model prior to the start of the school year. The major difference between the two classrooms was the ratio of students-to-computers. The study included fifth, sixth, and seventh grade classes.

Achievement

To determine program impacts on writing, we randomly selected for scoring and analysis 59 writing samples (fifth and sixth grades) from the laptop students and 59 from the CE students. The results from a one-way multivariate analysis of variance (MANOVA) showed substantial advantages in writing performance for laptop over CE students (sixth grade: $F(4, 53) = 8.87$, $p < 0.001$; seventh grade: $F(4, 55) = 4.133$, $p < 0.005$). Overall effect sizes were strong, ranging from +0.55 (Conventions) to +1.14 (Ideas and Content).

Random samples of 52 laptop and 59 CE students in the sixth grade completed the problem-solving assessment. A MANOVA comparing the means of the two groups on the seven components of the problem-solving rubric yielded a highly significant difference, $F(7, 103) = 3.378$, $p = 0.003$. Follow-up analyses showed significant advantages for the laptop group on all seven components: understands problem, identifies what is known about the problem, identifies what needs to be known to solve the problem, determines how the data need to be manipulated to solve the problem, describes use of technology, describes how to present findings, and collaborative learning. Effect sizes ranged from +0.38 to +0.76.

Classroom Observations

A total of 55 (32 laptop and 23 CE) observations using the SOM and SCU were conducted during the year. There were two significant differences on the SOM instrument: Integration of subject areas was *less* ($p < 0.001$) frequently seen in laptop than in CE classes. On the other hand, technology as a learning tool was *more* ($p < 0.001$) frequently seen in laptop than in CE classes. These analyses revealed much more similarity between the laptop and CE classes than was found in the Year 1 comparison between laptop and traditional classrooms.

Surveys, Interviews, and Focus Group Data

More laptop students felt highly positive that their computer skills had increased, and that using the computers improved their skills in writing to some degree, as compared to CE students (both p's < 0.001). In the focus groups, laptop students indicated that the best things about having the computer were easy access to online resources, ease of creating and editing work, and ability to make assignments look much better. The CE students stated that the best part was that it was easier than writing assignments with paper and pencil, that research was easier, and that they liked the spell checker. For CE students, the worst part was waiting to use a computer, forgetting to save work, and experiencing technical difficulties.

The eight laptop teachers all agreed that the program experience increased their personal ability to use basic computer applications, create lessons that integrate student use of computers, and integrate technology into lessons that were previously taught without computers. About two-thirds agreed that they had increased their emphasis on higher-level learning in the classroom, project-based learning, or interactions with parents and students as a result of participating in the laptop program. All teachers agreed that participating in the laptop program was personally beneficial, and that they would like to participate in the program again next year.

More than half of the laptop parents and CE parents surveyed attributed to their child's program improvements in their child's interest in school, involvement in projects, and research skills. Additionally, 57% of the laptop parents (vs. 20% for CE) believed that improvement in writing skills was attributable to computer usage, and 49% (vs. 27% for CE) believed that improvement in achievement occurred.

Year 3

The research in Year 3 focused on the fifth-grade students. The purpose of the Year 3 study was to determine the effectiveness of providing fifth-grade students with access to laptop computers and if differences occur based on the amount of time (24 hours per day vs. class-time only) and/or type of access (personal laptop vs. laptop on school mobile cart) to the computers. Each student in the laptop-cart classroom ("cart") had access to a laptop computer during class. Thus, the ratio of students-to-computers was 1:1 in both groups. Teachers in both groups had received training integrating computer technology using the NTeQ model. This was the first year of participation in the project for all the students as the fifth grade was the entry level in the district for the project.

Achievement

A total of 272 writing samples (140 laptop and 132 cart) were scored using the district's writing rubric. Mean performance scores for laptop and cart students were analyzed by group via a one-way multivariate analysis of variance (MANOVA) with the four dimension scores serving as the dependent variables. The MANOVA yielded a highly significant difference, $F(4, 267) = 9.16$, $p = 0.001$. Follow-up analyses showed significant advantages for the laptop over cart students on all four components, as seen in effect sizes ranging from $+0.33$ to $+0.63$. Effects of this magnitude represent strong and educationally important impacts (Cohen, 1988).

A total of 138 laptop and 134 cart students completed the problem-solving task. To determine if significant differences existed between the groups, a MANOVA was conducted to compare the laptop and cart problem-solving scores. The results depicted a significant multivariate effect, $F(7, 264) = 4.60$, $p < 0.001$. Follow-up analyses of univariate effects revealed that the laptop scores were significantly higher on five of the seven components: use of technology (laptop $M = 1.69$; cart $M = 1.31$), what is known (laptop $M = 1.47$; cart $M = 1.26$), presents findings (laptop $M = 1.56$; cart $M = 1.37$), understands problem (laptop $M = 1.68$; cart $M = 1.50$), and manipulates data (laptop $M = 1.89$; cart $M = 1.72$). Upon examination of the resulting effect sizes of the differences, the implied educational impact ranges from high for use of technology ($ES = +0.55$) to somewhat limited for manipulate data ($ES = +0.26$).

Mean raw scores (*M),* and standard deviations (SD) were computed for mathematics (benchmark 1–4), science, and social studies tests and the fourth-grade MEAP (2001–2002) raw scores were used as a covariate. Results from an independent *t*-test revealed that the laptop students fourth-grade mathematics MEAP scores were significantly higher than the scores for cart students ($t(431) = 4.51$, $p < 0.001$, $ES = .45$). In addition, the means for laptop students were directionally higher than the means of cart students on all tests. The MANOVA yielded a significant overall program effect: $F(6, 245) = 5.67$, $p < 0.001$. However, the univariate ANOVAs conducted on each test produced a significant effect on Mathematics Benchmark 2 only, with the laptop students scoring significantly higher $F(1,250) = 20.99$, $p < 0.001$ than the cart students (laptop $M = 89.32$; cart $M = 77.83$). The effect size for this difference was $ES = +0.44$, indicating a strong effect favoring the laptop group.

Observations

A total of 28 classroom observations were conducted, with 19 in laptop classrooms and 9 in cart classrooms. The SOM data revealed relatively few differences in teaching methods between laptop and cart classes. This is not surprising considering that both the laptop and cart teachers were trained in the NTeQ model and had substantial access to computers for instructional purposes. Thus, both groups of teachers were similar in the degree to which they acted as coach/facilitators, engaged students in sustained writing, and the use of computers as a learning tool or resource. Comparisons were made between the laptop classes and the cart classes on the seven RSCA items (cooperative learning, project-based learning, higher-level questioning, experiential/hands-on learning, student independent inquiry/research, student discussion, and students as producers of knowledge using technology) using the independent *t*-test. The results indicated that there were no statistical significances between the two groups of classes.

Although no significant differences were found between the laptop and cart classroom observations, data from the SCU revealed moderate advantages for the laptop over the cart students. For example, although students in both the laptop and cart classes primarily worked alone on up-to-date, Internet-connected computers, the majority of the laptop students were considered to have very good computer literacy and keyboarding skills as compared to only one-third or less of the cart students. Word processing was the most frequently used software by both groups; however, laptop students used the Internet more frequently than the cart students. Across both groups, language arts was most frequently the subject area of the computer activities, yet, computers were used to a lesser degree for social studies, science, and mathematics.

Surveys, Interviews, and Focus Group Data

Although both student groups indicated positive reactions to the personal impact of using laptop computers, laptop students were significantly more positive regarding increased computer skills, having more fun, being more interested in learning, and wishing to get better grades. The groups were also significantly different in all three categories of usage, with the laptop students indicating that they were much more likely to use their computers alone every day and to work in pairs several times a week. When looking at student laptop use by subject area, laptop students were significantly more likely than cart students to respond that they used laptops for language arts, mathematics, social studies; however, to a lesser degree than for language arts. No significant differences between the groups emerged for science.

As a group, the teachers conveyed positive reactions about the benefits of students using laptops as a learning tool. However, the laptop teachers in general reported higher agreement than cart teachers that the use of laptops had increased their personal ability to use computers, to integrate student use of computers into lessons, and to use higher-level and project-based learning in the classroom. There was unanimous agreement that participation in the laptop program increased students' interest in learning. Nevertheless, the laptop teachers had greater agreement that the laptops helped to increase student writing and research skills, and the ability to work with other students. The majority of the laptop teachers also indicated the laptops had increased student performance/grades. There were no notable difficulties reported regarding student use of laptops in the classroom.

Discussion

This project examined three different approaches for making technology accessibility to students in the classroom. The first approach required parents to lease or purchase a laptop computer for their child that would provide the student with 24/7 access to the laptop. In the second year, the district established several computer-enhanced classrooms that had approximately six desktop computers. Third, the district implemented laptop carts shared by several teachers that would provide each student in the class with a laptop for use during class time. These hardware innovations were also paired with a specific instructional approach and teacher training that focused on integrating the technology as a tool. From the teachers' perspective, the hardware (i.e., computers) and instructional approach were presented as a single innovation rather than as two separate innovations or steps to implementation. The following is a discussion of the results organized by research questions rather than by year. This perspective will provide insights into the role of the technology and instructional method as a change agent.

Research Question 1: Is Teaching Different in a Laptop Classroom?

The first-year comparisons provided the most extreme contrast of the 3 years in that the laptop classrooms were compared to traditional classrooms that had a limited number of computers (1–4). In addition, the laptop teachers received training in how to integrate the laptops by using them as a tool to solve problems. Data from the first year suggest that teaching in a laptop classroom was different than teaching in a traditional classroom. Observations of the classrooms revealed that the laptop teachers were more likely to use student-centered approaches such as project-based learning, independent inquiry/research, sustained writing, and cooperative learning. Similarly, the laptop teachers were more likely to use higher-level instructional feedback, use computers as a learning tool, and serve as facilitators that support a student-centered approach. A student-centered approach to instruction has been advocated in the literature for several years (Cobb & Bowles, 1999; McCombs, 2003; Zimmerman, 1990) suggesting we might expect to see frequent examples of this strategy in all classrooms, not just a computer-intensive classroom.

There are two potential explanations for these differences in the use of student-centered learning strategies. First, the students had ready access every day to the laptops, thus eliminating additional planning (and related frustration) by teachers to ensure that they could implement a learner-centered lesson incorporating computers. In addition, the lesson could span across several days without worrying about the availability of computer access. Second, the teachers were used to working in teams in the core content areas. Because all the team members had attended the training, the team and peer pressure may have provided additional support for implementing the student-centered approach.

In Year 2, the laptop classes were compared to CE classrooms that had five to six desktop computers available to the students in each classroom. In addition, the teachers in both groups completed training on the NTeQ model and were proficient in using the Internet and Microsoft Office. In contrast to Year 1, there were fewer observations of student-centered instruction in the laptop classrooms. While the Year 2 laptop classes were certainly busy and active places compared to typical classrooms that were observed in other studies (Ross, Smith, Alberg, & Lowther, 2000), perhaps the teachers were less influenced by a “Hawthorne-type” effect than in Year 1, and thus were less likely to demonstrate “model” lessons. There were two significant differences in Year 2. First, the integration of subject areas was observed less frequently in the laptop classrooms. Second, the use of technology as a learning tool was observed more frequently in the laptop classrooms. Laptop students also demonstrated superior computing skills and more frequent use of word processing and use of CD-ROMs for research.

The observation data in Year 3 identified relatively few differences between the laptop classrooms and the laptop-cart classrooms. Since both groups of teachers had the NTeQ training and relatively unlimited classroom access to computers, we would expect few differences. Both groups of teachers were observed serving as facilitators, using sustained writing activities, and using the computers as tools for learning. Of greater concern was the infrequent observation of cooperative learning, higher-level feedback and questioning, project-based learning, and integration of subject areas by *both* groups of teachers. These strategies, associated with best practices and improved student learning, were frequently observed in the laptop classroom in the first year of the study. Anecdotal data suggest that the teachers were modifying the NTeQ model to provide a simpler approach to integrating computer technology after the Year 1. Less emphasis was placed on project-based learning and more emphasis on using computers as a research tool for more traditional classroom activities. The training for teachers in Year 3 of the project was conducted by the school district which provided the teachers with more freedom to present and implement a modified approach. Rogers (2003) refers to this phenomenon as reinvention which is the degree to which an adopter modifies an innovation during adoption and implementation.

The results in this study are quite different from those of earlier studies. Earlier studies have found computer technology used primarily to deliver instruction (e.g., drill-and-practice and tutorials), to deliver presentations, for word processing of papers, or for searching the Internet (Becker, 2000; Cuban, Kirkpatrick, & Peck, 2001). Similarly, these studies did not find a change in teaching practices of the teachers. One reason for the difference may have been the lack of or limited teacher training. Based on the research results, one might conclude that the training focused more on how to utilize the computer rather than on how to *integrate the technology*. These studies reported primarily low-level uses of the technology that focused on strategies to enhance recall. In contrast, the training in the present study focused on higher-level integration of the technology that emphasized the development of problem-solving and critical thinking skills. The observation data suggest that teachers implemented these higher-level integration strategies into their classroom teaching in laptop, laptop cart, and computer-enhanced classrooms.

Research Question 2: Do Students Behave Differently in a Laptop Classroom?

Students in the laptop classroom during Year 1 demonstrated a different set of behaviors than students in the traditional classroom. Students in laptop classrooms were more active, autonomous, and worked in collaborative groups, which was most likely the result of the use of project-based learning. The observations were also confirmed by the laptop teachers' interviews and surveys, which indicated that the students were more independent, active, and engaged. While two-thirds of the laptop students were observed working individually in the classroom, they were frequently observed collaborating with others in sharing information, asking questions, and providing assistance.

The differences observed in the classrooms in the first year were not observed in the second year. Students in the CE classrooms behaved similarly to the laptop students. Laptop students tended to make more frequent and extensive use of their computers and were more likely to work independently. These observed behaviors may be due to the access provided for laptop students owning their computer. Students in the CE classroom had to either work together while sharing a computer or take turns using the limited number of desktop computers.

As in Year 2, we found no differences between the laptop and cart student behaviors in Year 3. Both groups tended to work independently and the laptop students were more likely to be engaged in independent inquiry, but not significantly so. The computer activities were considered somewhat meaningful with the laptop students engaging in more meaningful activities than the cart students.

Research Question 3: Do Students Achieve Differently in a Laptop Classroom?

The data from all 3 years provide evidence that the students in the laptop classrooms did achieve differently than the comparison group. In Year 1, achievement data consisted of a writing sample with a significant positive effect favoring the laptop students. The effect sizes for the four dimensions of the rubric ranged from $+0.61$ to $+0.78$ suggesting a strong effect.

In Year 2 of the study, the data also revealed significant differences in the writing performance between the laptop and CE students. The majority of the effect sizes exceeded $+0.80$ while the mean differences in many cases approximated or exceeded one full rubric point. Our observations did not find a difference in sustained writing activities in the two classes. However, there was a significantly greater use of word processing by the laptop students. Survey responses of laptop students and teachers indicated that they felt their writing skills had improved. Another factor may have been the ratio of students to computers, with the laptop classrooms having a 1:1 ratio while the CE classrooms varied with a typical ratio of four or five students per computer. During a typical 60-minute class, a student in the CE classroom might only expect 5–10 minutes of computer time compared to the 45–50 minutes afforded in the laptop classrooms. This limited time on task for the CE group may have resulted in the lower computer literacy and keyboard skills resulting in lower writing ability when compared to the laptop students.

Results of the problem-solving assessment added in Year 2 of the study also revealed that laptop students demonstrated superior problem-solving skills. The frequent engagement of laptop students in research activities as indicated by the surveys and interviews may have contributed to their performance. The combination of greater engagement in problem-solving activities and having nearly unlimited access to the application software and Internet may have provided additional opportunity for the students to develop and refine their problem-solving skills.

Three new research questions focusing on student achievement were added in Year 3. The following paragraphs provide a discussion of each of these questions.

Do Laptop Students Differ from Cart Students in Their Writing Skills?

Results from Year 3 followed the same trend in writing-performance differences as observed in the first 2 years. The laptop students showed significant advantages over the cart students, although the differences were directionally lower than in Year 2. These findings suggest that students with 24/7 access to laptops have advantages over those who only use laptops during class, and even a greater advantage over students in classrooms limited to six or fewer computers shared by all students.

The observations did not find any significant differences in teaching approaches between the two groups. The laptop students did use word processing software and accessed the Internet during language arts classes and when doing independent inquiry/research more frequently than the cart students. Student responses to survey items also revealed that a majority of the laptop students indicated an increase interest in learning and in overall computer skills. The combination of 24/7 computer access and the above factors may have contributed to the increased writing performance of the laptop students. Teacher training in the NTeQ model and classroom access to laptop computers with wireless Internet access were the same in both groups.

Do Laptop Students Differ from Cart Students in Their Approach to Problem Solving?

Laptop student outperformed the cart students on the problem-solving assessment. However, as with the writing test, there was a Year 2–Year 3 decrease in the effect sizes of these differences. The effect sizes for Year 2 ranged from +0.38 to +0.76, whereas the Year 3 range was only +0.26 to +0.55.

Although there were no significant differences in teaching approaches between the two groups, the laptop group was more frequently engaged in independent inquiry/research and access to the Internet which could enhance the students' problem-solving ability. The laptop students also reported significantly more use of their computers in mathematics and social studies classes where teachers might have found it easier to integrate problem-based learning activities. Laptop students also indicated that they more frequently engaged in cooperative learning which required students to work and process information together. The combination of these factors may have created an instructional environment conducive to the development of problem-solving skills.

Do Laptop Students Differ from Cart Students in Their Mathematics, Science, and Social Studies Achievement at the Fifth-Grade Level?

A comparison of district benchmark assessments in mathematics, science, and social studies only found a significant differences on the Geometry and Measurement benchmark with a moderate effect size ($ES = +0.44$) favoring the laptop students. Since use of the fourth-grade MEAP scores as a covariate addressed the initial laptop student advantage, the difference is not likely to be attributed to the laptop students just being "better" students. Again, laptop students' advantages might be the result of the more frequent use of independent research, higher-level questioning and feedback, project-based learning activities, and the use of draw/paint/graphic applications in the laptop classrooms. Although the differences in teaching methods between the two classrooms were not significant, the more frequent use of higher-level learning strategies and student-centered activities over time may have contributed to the effect.

How Do Students Perceive the Use and Access of Laptop Computers?

Survey data from all 3 years indicated that the laptop students had a positive attitude toward the program. In Year 3, both groups indicated a positive benefit for the 1:1 student-to-computer ratio. However, there were significant differences between the students who owned their computers and had 24/7 access and those who only had access in the classroom. The laptop students were significantly more positive about their increased computer skills, that learning was fun and interesting, and that the computer provided an incentive to get better grades. Personal ownership led to more individual use of the laptop as well as working in pairs several times each week. The subject areas of computer activities were also significantly different in laptop versus cart classes. The laptop students responded that they used laptops for language arts almost every day and were more likely than cart students to use them for mathematics and social studies, but to a lesser degree than for language arts. No significant differences between the groups emerged for science. These results suggest that students have a more positive attitude toward the educational benefits of a computer when they own it and have access 24/7 as opposed to having limited access to a school computer.

What Do Teachers Perceive as the Benefits and Problems of Integrating Technology in Laptop Versus Cart Classrooms?

The last research question addressed teacher perceptions of the ownership of laptops versus using school-provided laptops. The limited number of responses (laptop = 9; cart = 3), can only suggest trends in teacher thoughts. Consistent with the student responses, teacher perceptions of the benefits of the laptop computers were positive. All the teachers agreed that the 1:1 access increased the students' interests in learning, although, the laptop teachers were in greater agreement than were the cart teachers that the use of the computers increased student writing and research skills as well as their overall performance. Laptop teachers were also in higher agreement than the cart teachers that the laptop increased their own personal ability to use computers, integrate the technology, and to use higher-level and project-based learning activities. Last, the laptop teachers may have felt additional accountability to the parents who had to purchase the laptops for their children and gave additional consideration to using the computers every day.

Did the Laptop Computers Serve as a Change Agent?

The results from this 3-year project provide three distinct snapshots into technology integration, each with different results. Of primary interest are the teaching approaches and how those approaches affected student behaviors and achievement.

In Year 1, the evidence supports the idea of the innovation as a change agent. There were dramatic differences between the approaches that the laptop and traditional teachers employed during the year. The laptop teachers were more likely to use a student-centered approach and methods that were considered best practices. A student-centered approach was not a new concept to the teachers, yet the teachers in the laptop classrooms were more likely to implement the approach. We believe there were three factors that contributed to the change.

First, two pieces of anecdotal evidence may provide a perspective. The students received their laptops in early July giving them almost two months to explore and learn the Windows interface, explore the Web, and to explore Microsoft Office. Two events happened in almost every classroom soon after the school started. The first was a technical problem (e.g., "I lost my assignment.") and second was a student wanting to know how to do something (e.g., "How do I put a spreadsheet into a report?"). Teachers soon realized the limitation of their knowledge and readily recognized the knowledge and skills of individual students. Good teachers soon realized they were behind the students' learning curve and readily adopted a facilitator's role. When a problem arose, the teachers quickly lost their fear of not knowing and took advantage of student knowledge or the students' willingness to experiment to find the answer. During a parent meeting, a father who considered himself a power user admitted that he was now learning quicker and better ways of performing routine tasks from his sixth-grade daughter. The 24/7 access afforded by the laptop project provided students with ample opportunity to not only work, but also to experiment with their computers (it was not unusual to see a host of interface customizations and downloads the students had on their computers when visiting a classroom). In contrast, is the typical classroom with 1–6 computers that students could use infrequently. As a parallel constraint, imagine the effects on teaching, learning, and student engagement of having only one sheet of paper and one pencil in a classroom.

Our second piece of anecdotal evidence comes from a science class. In a traditional classroom, the classroom is defined by the four walls, the textbook, and the teacher's expertise in the subject. If the teacher does not know the answer to a question, she typically suggests that the student research the answer at the library and report back. While observing a science class, a student asked about the gestation period of a mammal they were studying. Before the teacher could suggest that the student do the research in the library, several hands were raised. Students had used their wireless Internet access to search for the answer. Again, the teacher began to facilitate a new discussion as the class topic wandered to a related area.

A second factor that contributed to technology serving as a change agent may have been the change from the teacher as *the* expert to one of a facilitator willing to learn and discover new ideas with the class. The successful laptop teachers readily discovered that the students were able to use their laptop computers in a manner different than the traditional textbook. The classroom was redefined from almost the first day of the school year. The laptop classrooms were typically very active. It was not unusual to hear the teacher address the class only one time at the start of session when he would announce "Let's get started." The classroom then became a buzz of activities with small groups of students and individuals spread around the room, some sitting at desks and others working comfortably on the floor.

A third contributing factor may have been the training and support system. The teachers attended training that focused on how to develop problem-based units of instruction and how to facilitate the classroom using this approach. The training may have helped them gain confidence in using a new or different teaching method. Similarly, the district administrators provided direct support to the teachers and demonstrated their interest in the project. The assistant superintendent who directed the project maintained a supportive and visible presence in meetings and schools. Teachers were already used to working in teams and planning their lessons, so this new approach was compatible with their existing framework. As a result, the teams may have provided support and peer pressure for individual members to implement a consistent approach in their team-taught clusters.

Was the Innovation Sustained?

We have defined the innovation in this chapter as consisting of two components – the laptop computers and implementation of the NTeQ model. The 3-year study examined three different implementations of the innovation. In the first year, the comparison was between the NTeQ-trained laptop teachers and teachers in a traditional classroom. It was in the first year that we observed the greatest difference in implementation of teaching approaches.

In Year 2, both groups of teachers had completed training in the NTeQ model. The primary difference was the technology with the laptop classes having a 1:1 student-to-computer ratio and the CE classrooms having 4–5:1 student to computer ratio (the NTeQ model was developed for this type of implementation). In Year 3, laptop carts were used which provided each student in the classroom with a computer.

Seven of the behaviors observed in the classroom with the SOMs instrument were selected for comparison across all 3 years (see Table 1). These behaviors are consistent with the NTeQ model and would be expected to be demonstrated by teachers who had completed the training.

Of particular interest is the use of project-based learning activities since these are the focus of the NTeQ model. During Year 1, there was a significant difference in the observed frequency of project-based learning between the laptop (64%) and control groups (22%). In subsequent years, we would expect to find little if any difference between the groups as all teachers had received the NTeQ training and had access to computers in the classroom. More importantly, we would expect the laptop classrooms to maintain a fairly high frequency of project-based learning. There were no significant differences between laptop and comparison groups in the second and third years. Of note, the frequency of observed use of project-based learning in the second and third years in laptop classes dropped to the level of the control group in Year 1. Because project-based learning is central to the NTeQ model, what was the

Table 1 Percentage of SOM visits in which the strategy was observed being used

	Year 1	Year 2	Year 3			
	Laptop (%)	Control (%)	Laptop (%)	Enhanced (%)	Laptop	Cart (%)
Project-based learning	65	22	23	30	10	0
Independent inquiry	58	24	37	22	50	11
Computer as learning tool	88	17	66	17	80	100
Cooperative learning	66	39	22	17	10	11
Higher-level instructional feedback	61	39	59	35	50	22
Teacher as facilitator	72	61	56	52	80	78
Sustained writing	53	39	34	29	40	56

effect of the lower frequency of use on the related teacher behaviors? One explanation for the higher-observed frequency of project-based learning during Year 1 may been due to a Hawthorne effect. The teachers were the focus of much attention during the year and observed frequently by administrators, the research team, and individuals from other districts who were interested in implementing the project. In subsequent years, the laptop teachers may have lost some of their enthusiasm and started to modify the NTeQ approach to suit their teaching style and needs.

There were six other observed behaviors that are consistent with the NTeQ approach. The laptop teachers maintained a somewhat consistent use of four of these approaches (independent inquiry/research, computer as learning tool, higher-level instructional feedback, and teacher as facilitator) during the 3 years. The observed use of sustained writing and cooperative learning both decreased over the second and third years. During the 3 years, it appears that the laptop and other computer teachers re-invented (Rogers, 2003) the innovation to meet their needs. Conversations with teachers during the third year indicated that they had made modifications in both the training and implementation of the problem-based approach for the third year. These modifications may explain the drop in project-base learning activities during the second and third year of the project, but the consistent use of other approaches. Comparing the observations in Years 2 and 3 to national norms (CREP, 2006), we found that the laptop, computer-enhanced, and laptop-cart teachers demonstrated these six behaviors more frequently than the national norms suggesting changes in the classroom where teachers were trained in the NTeQ model and had access to computers in their classrooms.

Conclusions

The evidence from this 3-year study suggests that a technological innovation can serve as a change agent. We were able to observe significant differences in teaching approaches and student behavior during the first year when the laptop classrooms were compared to traditional classrooms. As the classroom environments became more similar in Years 2 and 3, we observed fewer differences but consistent use of teaching approaches and student behaviors that commensurate with the NTeQ approach. The results were classrooms that were transformed from teacher-directed to student-centered classrooms.

The combination of the student "owned" laptops and the transformed classroom environment resulted in sustained student achievement. Each year, the laptop students demonstrated significantly higher writing scores than the comparison groups. They had a significantly higher problem-solving scores than the comparison groups in Years 2 and 3. In Year 3, we examined the District's benchmark scores and only found a significant difference favoring the laptop students on one aspect of the mathematic exam. It appears that the transformed classroom was most effective for developing writing and problem-solving skills. The 24/7 access to the computers may be one contributing factor to this success. Laptop students were able to do their research and write anytime, anywhere. Anecdotal evidence suggests that students often asked teachers for permission to work on projects rather than use free time or lunch time. Sustained writing related to their individual research may have been more engaging than a typical social studies, language arts, mathematics, or science lesson. There is no evidence to suggest that teachers used a problem-based learning approach for *all* their lessons. We would suggest that computer technology is not limited to a limited role in student learning as suggested by Cuban (Becker, 2000) .

We have two recommendations for future implementations of technology projects. First, technology hardware should be accompanied with an appropriate instructional approach. Simply handing teachers and students computers without focused training does not seem to work. Second, evaluators and researchers should take a systems perspective that is more global than simply considering attitude and/or achievement gains. Studies should be broadened to focus on changes in teacher and student behaviors as well as attitude and achievement changes.

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Using Activity Theory to Evaluate and Improve K-12 School and University Partnerships

Lisa C. Yamagata-Lynch and Sharon Smaldino

Abstract This chapter reports on an evaluation methodology development study for K-12 school and university partnerships. The method is based on Engeström's (1987) activity systems analysis that allows researchers to examine qualitative datasets of complex human interactions. This study was designed for participants to evaluate partnership relations and activities. We investigated how the use of activity systems analysis in K-12 school and university partnership evaluation meetings affected participant communication processes. In this study, during a one day retreat K-12 school staff and university staff used a modified activity systems model to identify persisting institutional tensions in their program that often trigger miscommunications and strain their relations. During the discussion sessions, study participants collaboratively examined their partnership relations and identified strategies for overcoming difficulties. Additionally, in subsequent monthly partnership meetings during the school year, participants examined findings from the evaluation to design and implement improvement strategies. The results from this methodology development and implementation study provided researchers and partnership participants a new means to (a) evaluate partnership activities, (b) identify institutional barriers, (c) plan future activities, and (d) listen to and incorporate the ideas of less vocal staff members into the planning of future activities.

Keywords K-12 · Activity theory · K-12 university partnerships · Systems analysis · Communication · Collaboration · Practical theory approach · Teacher professional development · Preservice/inservice training · Standards-based education reform · Vygotsky · Organizational change · Consensus building · Education stakeholders · Instructional technology.

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Introduction

In this chapter, we report on a new evaluation method based on activity systems analysis (Engeström, 1987). We developed this method for K-12 school and university partnership participants to use as an organizing framework for discussions identifying recurring institutional tensions and planning strategies to overcome them. The goal of this investigation was not to predict future partnership outcomes, but to develop a theoretically based method to evaluate, plan, and implement new partnership activities.

While developing this method we took a practical theory approach, which is concerned with how theory and research can be applied to improve practice (Barge, 2001). Researchers who pursue practical theory investigations are interested in solving actual problems in practice rather than focus on the ability to understand, predict, and control events (Craig & Tracy, 1995). These investigations involve an iterative process grounded in empirical studies that require researchers and practitioners to find new meaning to both theory and practice by applying abstract concepts to concrete situations through reflective discourse (Craig, 1996). In partnerships between complex organizations, communication activities can help create opportunities for theory and practice to inform one another (Barge & Little, 2002).

For this study, we modified an existing activity systems analysis model that accommodated the complex nature of school and university partnerships. We modified the model so that the theoretical constructs in activity systems analysis would be easily understood by participants and so that partnership member discussions would be focused to address specific program difficulties stemming from institutional tensions. At the same time, we asked participants to focus their partnership related discussion surrounding the model so that we would be able to find how specific theoretical constructs of the model assisted their communication processes.

K-12 School and University Partnerships' Background

Partnerships between K-12 schools and universities have been identified as a strategy for preparing and supporting better teachers (Clark, 1999; Goodlad, 1994). The intention has been that schools and universities would contribute to teacher education and K-12 student educational renewal processes. Through this process both schools and universities are encouraged to engage in joint research and development of preservice, inservice, and K-12 school and university curriculum.

Recently, both K-12 schools and universities have felt hard-pressed by the demands of reform programs to meet state and national standards (Delandshere & Petrosky, 2004; Gore, Griffiths, & Ladwig, 2004). Such demands have been fueled by the public perception that teacher education programs and teachers are both inadequate and are responsible for the failure of schools in this country (Kincheloe, 2004). In order for both K-12 schools and universities to meet these demands, many national accreditation agencies now require colleges of education and K-12 schools to be in partnership relationships to support standards-based educational reform.

Due to the organizational differences between schools and universities, partnerships find that maintaining consistent communication alone becomes an overwhelming task (Edens, Shirley, & Toner, 2001). Unlike many business partnerships, individuals involved in K-12 and university partnerships do not necessarily share a clear sense of vision, mission, or goals of the partnership or at times of their own institution. Individuals who are involved in partnership activities are often not administrators who have direct influence on institutional goals. Consequently, partnership participants find it very challenging to clearly communicate to one another what their institutional goals are in order to build mutually beneficial relations.

Institutions involved in K-12 and university partnerships have not identified an appropriate solution to this problem. As a result, many partnerships have not been able to meet their goals for enhancing teacher education, teacher professional development, and K-12 student educational renewal (Day, 1998; Lieberman & McLaughlin, 1992; Simpson, Robert, & Hughes, 1999). Presently, partnerships are in a dire need of methods that would help them overcome their institutional differences to maintain effective communication.

For university and K-12 school partnerships to truly achieve their goals, the institutional differences between universities and K-12 schools need to be addressed. These differences stem from the considerable misalignment in beliefs between schools and universities regarding what is legitimate theory and practice (Perry & Power, 2004). Many partnerships find themselves unable to establish shared goals when they do not pay attention to organizational differences (Bacharach & Hasslen, 2001).

In principle, both schools and universities endorse the idea of collaboration, but due to the history of mistrust and fundamental organizational cultural differences it has been very difficult to facilitate collaborative partnerships (Perry, Komesaroff, & Kavanagh, 2002). Furthermore, the mistrust between schools and universities has made it difficult for partnership participants to find mutually beneficial relationships (Teitel, 2003a). In many cases, partnership participants find it difficult to communicate with one another in order to agree on a common set of program goals.

Within the culture of mistrust found in many partnerships, the image of a coin with two sides comes to mind. On one side, universities are blamed for not providing usable research findings in teachers' practice. For example, in many cases partnership-based research that faculty conduct do not necessarily have results relevant to teachers' daily classroom activities and student achievement (Teitel, 2003b). When they are relevant, the teachers do not have a systematic implementation strategy that will allow the educational innovations to become part of everyday classroom practices (Blumenfeld, Fishman, Krajcik, & Marx, 2000). In other words, often times what university faculty bring to schools through partnerships are deemed to be unusable by classroom teachers. Teachers are often looking for quick practical applications of techniques or resources they can use in their classrooms rather than exploring the deeper theoretical underpinnings. In contrast, the other side of the coin, university faculty are looking to make connections with theory and practice that may not be apparent in teachers' classroom decisions. Faculty are often seeking information that can benefit their scholarship and potentially contribute to their publication agenda.

Origins of Activity Theory

Activity theory originated from the works of several Russian scholars (Hakkarainen, 2004), but in this chapter we will focus on Vygotsky's work in the 1920s, and post-Vygotskian psychologists in Russia, Finland, and the United States. Vygotsky worked to reformulate a unified psychology based on Marxian theory (Galperin, 1992; Luria, 1979). Vygotsky adapted Marx's political theory regarding collective exchanges and material production to capture the co-evolutionary process that individuals encounter with their environment while learning to engage in shared activities (Stetsenko, 2005). He wanted to develop a framework of psychology to understand the intricate relationship between individuals and their social environment (Cole, 1985; Wertsch, 1985).

Post-Vygotskian theorists in Russia, Finland, and the United States accepted Vygotsky's premise of psychology and proposed activity theory as a method for overcoming the divide in psychological research between the organism and the environment, and attempted to merge theory into practice (Hakkarainen, 2004). These researchers have found that this is a very difficult task. Unfortunately, the theoretical developments in activity theory have brought further divide between theory and practice (Lazarev, 2004; Stetsenko, 2005), and made activity theory a highly theoretical discussion that is not necessarily interesting to many researchers and practitioners. Activity theorists have not been able to inform theory or practice and have been finding difficulties in developing this framework as a formal methodology in research.

In order to advance activity theory as an informative framework for both theory and practice, Engeström (1987) developed activity systems analysis. Activity systems analysis became well known in North America after the wide circulation of Engeström's work through the publication of Cole and Engeström (1993) and Engeström (1993). This analysis method has become popular among educational researchers for mapping complex human interactions from qualitative datasets.

In Engeström's original work, activity systems included subject, tool, object, rules, community, distribution of labor, and outcomes as shown in Fig. 1. Subjects are participants of the activity and tools are the resources that subjects

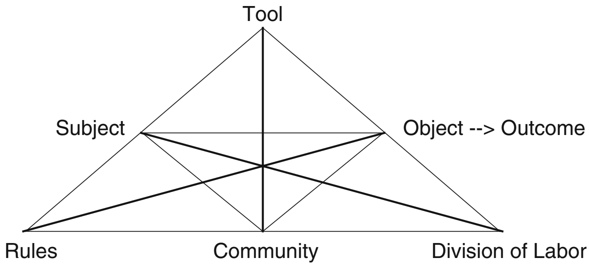

Fig. 1 Activity system adapted from Engeström (1987)

use to obtain the object or the goal. Rules can be informal or formal regulations that subjects need to follow while engaging in the activity. The community is the group that subjects belong to and the division of labor is the shared responsibilities determined by the community. Any component of an activity system can bring about tension in the subject's effort to attain the object. Finally, the outcome is the consequences that the subject faces as a result of the activity. These consequences can encourage or hinder the subject to participate in future activities.

Unlike strategic planning tools in the business sectors such as the balanced scorecard approach and SWOT analysis, activity systems analysis was not developed as an organizational planning tool. Instead it was developed to explore and document the sources of tensions in human individual or collective activities. Engeström (1987) originally introduced his model as a tool for participants to understand the complex psychological phenomenon involved in their activities and facilitate an iterative learning process. His intention was to help participants identify tensions in their practices and develop strategies to overcome them. By focusing on the psychological phenomenon involved in human activity, activity systems analysis allows the examination of collective action as a unit of analysis (Cole & Engeström, 1993; Engeström, 1987, 1993). It also provides opportunities to researchers for capturing (a) the dynamic structure of activity, (b) the historical development of activity over time, and (c) the multivoiced nature in the formation of human activity (Engeström, 1999).

Many applications of activity systems analysis within North American educational research have deviated from Engeström's original work. Applications of this method have focused on using it as a descriptive research tool in qualitative analysis and do not provide discussions on how this method assisted participants to develop strategies for solving tensions or the outcomes of new activities. For example, educational researchers have applied activity systems analysis to (a) summarize organizational change (Barab, Schatz, & Scheckler, 2004; Engeström, 1993); (b) identify guidelines for designing constructivist learning environments (Jonassen & Rohrer-Murphy, 1999); (c) identify contradictions and tensions that shape developments in educational settings (Barab, Barnet, Yamagata-Lynch, Squire, & Keating, 2002; Roth & Tobin, 2002); and (d) demonstrate historical developments in organizational learning

(Yamagata-Lynch, 2003). These studies have allowed researchers to appreciate how individual or group activities are closely bound by the social context, and demonstrate how individuals, groups of individuals, and the social context shape one another.

Research Context

Participants

The participants of this study were liaisons from eight of the nine school districts in partner relations with Northern Illinois University's (NIU) College of Education, and four university staff who were involved with coordinating and assisting ongoing partnership activities. School district liaisons chose to participate in the study voluntarily. One of the school district representatives was unable to participate because she had a prior professional commitment on the day we held the analysis.

School district liaisons. Six of the eight liaisons who participated in this study were elementary and middle school teachers. The other two liaisons had administrative responsibilities at their school districts, one as a building assistant principal and the other as a district-wide K-12 special education coordinator. In their partnership liaison capacity, both members with administrative backgrounds were recognized as fellow "teachers" from other liaisons. There were one male and seven female liaisons. The liaisons had varying years of experience of being a liaison ranging from just beginning to 7 years. Their teaching experience ranged from 3 years to 15 years.

As a liaison, their primary responsibilities to the partnership were to ensure coordination and communication within our partner relations. These activities included (a) coordinating preservice teacher placements in the school districts, (b) providing information to the district teachers regarding professional development opportunities, (c) providing the university with information regarding the professional development needs of K-12 teachers, (d) providing information to teachers regarding opportunities to be involved in university faculty research, and (e) participating in the development of a school district project. Liaisons attend 2-hour meetings on the NIU campus each month between October and May to coordinate and facilitate these activities with university and school personnel involved in partnerships. Liaisons were awarded a stipend at the end of each semester for fulfilling their responsibilities.

University staff. The four university staff who were involved in this study included two staff members of the college Clinical Placement Office and two faculty members who authored this chapter. Throughout the school year, the Clinical Placement Office staff work closely with the school district liaisons to place preservice teachers in partnership school district classrooms to meet candidate certification requirements. The first author of this chapter is a faculty member who has been a consultant to the NIU College of Education Partnership Office since the fall of 2004 and has been participating in various partnership activities with the Partnership Office, district liaisons, and the Clinical Placement Office. The second author has been the director of the NIU Partnership Office since the fall of 2003, and has been coordinating the partnership activities.

Partnership Struggles

Within the context of exploring theory into practice in school–university partnerships, the complexity of participating individuals and institutions can create barriers when evaluating partner relations and program accomplishments. Factors that may affect the continuation of the partnership relationship might include shifts in personnel, unclear channels of communication, and varying levels of responsibility for members of K-12 schools and universities. These factors can wreak havoc with the investigation of factors that influence successful school–university partnerships.

When looking at the specific relational struggles we had in our partnership, the effort to analyze contributing factors was difficult because participants were reacting to situational issues rather than trying to address the source of the problems that affected program activities and outcomes. For example, in arranging field placements for students, the discussion during meetings often centered on numbers of students, rather than on the underlying issues related to cooperating teachers, expectations, and assessment of the student performance in the schools and at the university in methods' courses.

Research Goals and Questions

In this study, we identified both practical and theoretical research goals to develop the new K-12 school and university partnership program evaluation method. As shown in Table 1, from a practical perspective we wanted to identify how K-12 school and university partnership staff can overcome institutional tensions to establish communication processes for evaluating and planning program improvements. At the same time, from a theoretical perspective we wanted to identify how the activity systems model can be used by research participants to recognize tensions in their work activities in order to overcome them.

The overarching research question that tied our practical and theoretical research interests was as follows: How does the new evaluation and planning tool based on activity systems analysis affect partnership meeting outcomes and develop new theoretical understandings? Specific practical research questions included.

Table 1 Research goals and questions

Practical research goals	**Theoretical research goals**
Identify how K-12 school and university partnership staff can overcome institutional tensions to establish communication processes for evaluating and planning program improvements.	Identify how the activity systems model can be used by research participants to recognize tensions in their work activities in order to overcome them.
Practice questions	**Theory questions**
How does the use of the modified activity systems analysis model as an organizing framework during partnership program evaluation and planning meetings affect participant communication processes?	How does the activity systems analysis model need to be modified for research participants to use as a tool to identify characteristics of their activities and overcome tensions?
What are the outcomes from implementing program improvement strategies that K-12 school and university staff collaboratively proposed during program evaluation and planning meetings?	How does the modified activity systems analysis model help research participants to recognize tensions in their activities and develop strategies for overcoming them?
Theory and practice merging question	
How does the new evaluation and planning tool based on activity systems analysis affect partnership meeting outcomes and develop new theoretical understandings?	

- How does the use of the modified activity systems analysis model as an organizing framework during partnership program evaluation and planning meetings affect participant communication processes?
- What are the outcomes from implementing program improvement strategies that K-12 school and university staff collaboratively proposed during program evaluation and planning meetings?

Specific theoretical questions included

- How does the activity systems analysis model need to be modified for research participants to use as a tool to identify characteristics of their activities and overcome tensions?
- How does the modified activity systems analysis model help research participants to recognize tensions in their activities and develop strategies for overcoming them?

Methods

Overview

Our practical theory research involved a methodology development process and an implementation and evaluation process as shown in Fig. 2. The development process involved modifying the activity systems model, identifying participant discussion topics for analyses, developing the discussion guide

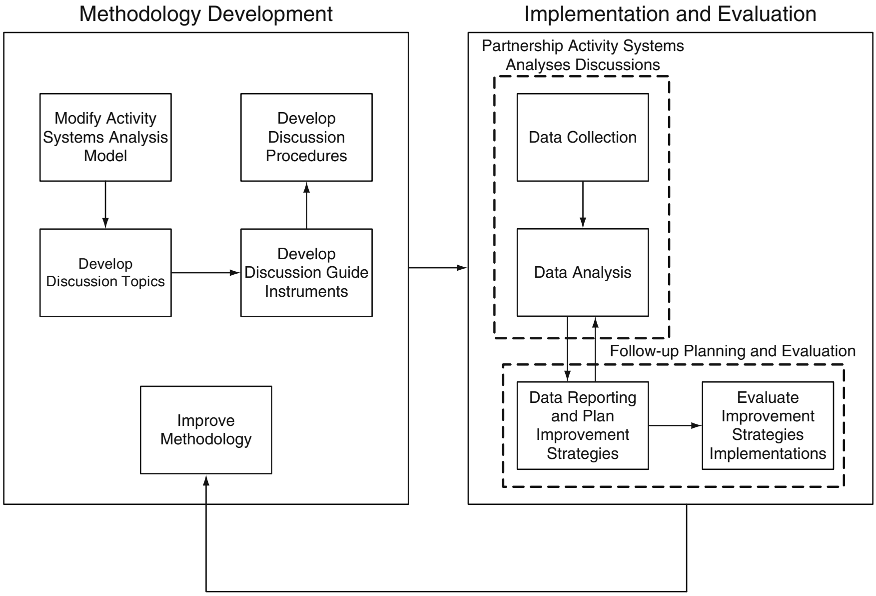

Fig. 2 Methodological processes

instruments, developing the discussion procedures, and improving the methodology based on findings from the implementation and evaluation. The two-phase implementation and evaluation process spanned over the 2005 and 2006 school years. The initial phase was the partnership activity systems analyses discussions that involved data collection and data analysis. The partnership activity systems analyses discussion took place during a one day retreat at the end of the 2004 and 2005 school year. During the retreat, study participants collaboratively examined their partnership relations and identified strategies for overcoming difficulties. The researchers then engaged in an analysis of the retreat discussion data. The second phase of the implementation and evaluation was the follow-up planning and evaluation that took place in subsequent eight monthly partnership meetings during the 2005 and 2006 school year. The follow-up involved reporting data to participants, planning improvement strategies, and evaluating improvement strategies' results. Additionally, the member checking took place during these follow-up meetings and participants provided feedback regarding the accuracy of the data representation.

Modifying Activity Systems Analysis Model

While examining the activity systems model, as researchers we agreed that the language used to represent various components of the model (i.e., subject, tool, object, rules, community, and division of labor) would not be easily understood

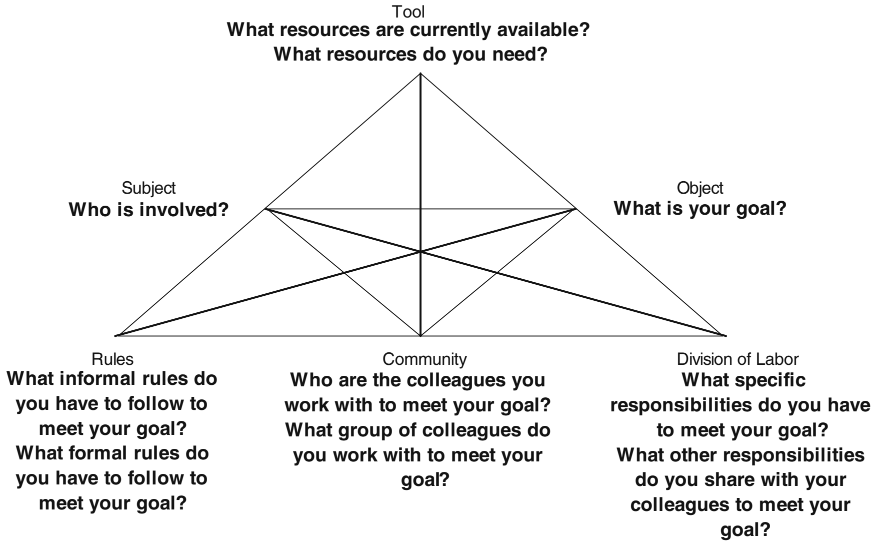

Fig. 3 Modified activity system for evaluation and planning meetings

by participants unless they had studied the theoretical literature. Therefore, the first modification we made to the model was to insert guiding questions for each component. As shown in Fig. 3, we added one or two questions related to each component of the model to help participants understand the model after being provided with a brief overview and a sample analysis. The questions were designed to guide participants in their specific analysis of partnership activities and institutional tensions.

Develop Discussion Topics

We also determined that the evaluation meeting discussions had to be organized in specific topics. In other words, we did not see that much fruitful discussion would take place if we were to present the modified activity system model to participants and ask them to conduct an analysis of their partnership activities in general. Additionally, we anticipated that identifying specific discussion topics would enable participants to contribute to some of the difficult discussions that they often avoid during our regular meetings.

To facilitate participants' discussion and analyses we provided them with specific topics. These topics included partnership goals, K-12 school partnership expectations, and university partnership expectations. We decided to focus the topics on individual and institutional goals and expectations because activity systems analyses isolates complicated human interactions into units of goal-oriented activities and often times starting the analysis by identifying goals and expectations is the first step for identifying other critical characteristics of the activity system (Yamagata-Lynch, 2007). We anticipated that it would help participants to start the analysis once they identified what they perceived to be individual and institutional goals. Additionally, in past monthly partnership liaison meetings, it was evident that many of our communication struggles stemmed from conflicting personal and institutional goals and expectations. As researchers and practitioners involved in partnership activities, we wanted participants to freely communicate to us their perspectives on the three topics; therefore, we did not provide any further guidance, examples, or discussion related to each topic.

Develop Discussion Guide Instruments

Once we modified the activity systems model and identified discussion topics, we developed the instruments shown in Figs. 4, 5, 6, and 7. We used Fig. 4 to provide participants with a general overview of activity systems analysis and a sample analysis of a specific partnership activity. Then we introduced Figs 5, 6 and 7 as guides for participants to use while engaging in specific analyses of partnership activities. During the meetings, groups of participants prepared an activity systems analysis of each discussion topic on poster-sized paper.

Data Collection During Partnership Activity Systems Analyses Discussions

With the school district liaisons and the partnership staff we conducted a series of group discussions to build consensus on the partnership goals and how those goals can be collaboratively achieved. The goal of these discussion activities was for participants to make new meaning of their practice by sharing ideas with other participants (Wells, 1999; Wertsch, 1998). Additionally, we wanted participants to experience a new sense of ownership of ideas that often follows community inquiry sessions (Bakhtin, 1986).

Discussion group participants were divided into two groups and each group was given three 45-minute sessions to conduct their discussion and analyses on the three topics. Each group was lead by a facilitator and engaged in this activity to create a graphic representation of analyses topics using the appropriate instrument in Figs. 5, 6 and 7. The analysis focused on understanding the school district liaisons' perspectives on partnership activities. Thus, university personnel including staff from the Clinical Placement Office and the two authors were involved as facilitators and summarizers of the two discussion groups. In each group, a university staff was assigned as the designated note taker for drawing the activity systems on a poster paper while district liaisons engaged in discussion and instructed how to draw the triangles. During the discussion process, school district liaisons evaluated the triangles on the poster paper and the tensions in partnership program goals, institutional goals, and personal goals. Then they

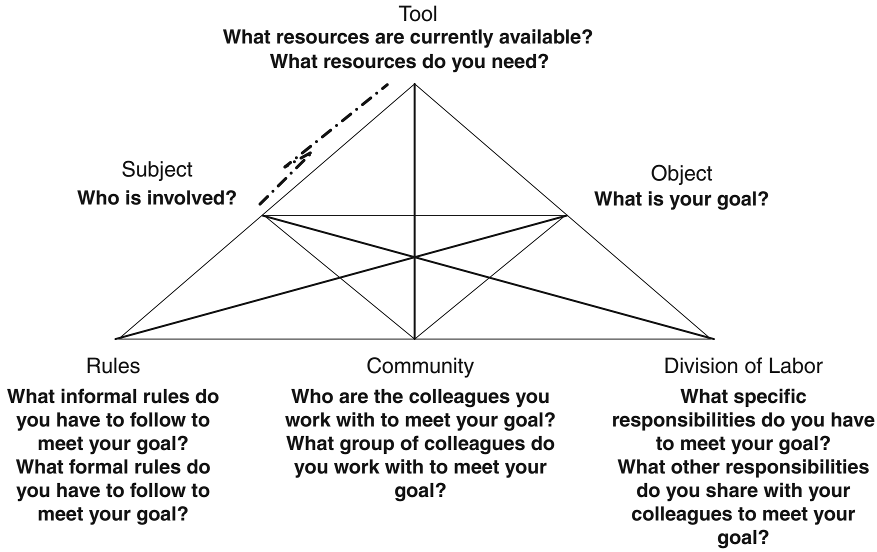

Fig. 4 General instruction for conducting an activity systems analysis

General Instruction on Using Activity Systems as a Graphical Communication Tool

An activity system is a graphical tool for mapping out complicated information in an organized manner so that you can isolate what are the most important factors that need to be addressed to improve your current practice. Additionally, this model helps to identify what areas are conflicting with one another and preventing you from meeting your goals. These conflicts are represented as a squiggly line between specific sections of the model. By identifying the areas of conflict, you will be able to strategize how to better approach your goal. The graphical model consists of the points mentioned in Fig. 4.

Today you will be using the above graphical tool to map out the important issues that we need to address in our partnership efforts regarding the following topics:

- Partnership goals
- K-12 partnership expectations
- COE partnership expectations

If you have any questions regarding the above model, please do not hesitate to ask Sharon Smaldino or Lisa Yamagata-Lynch.

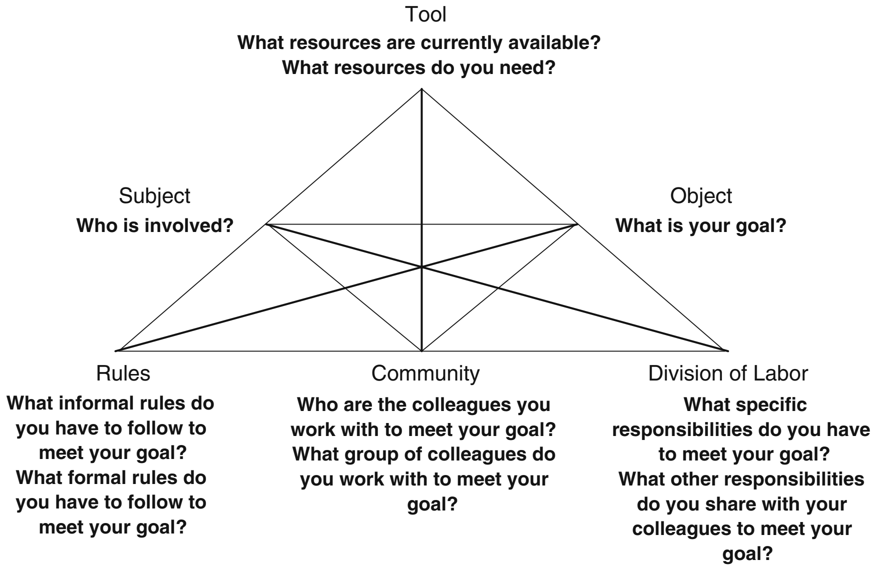

Fig. 5 Instructions for conducting activity systems analysis on partnership goals

Partnership Goals Activity Systems Analysis Discussion Question

In your group, please discuss what you think the partnership goals are. Please use the following graphical model to clarify what to include in the Subject, Tool, Object, and any other areas you feel are important to map out when identifying the goals. Please indicate any specific conflicts between areas of the model with a squiggly line. While creating the model in your group, please make sure that you take notes to share your ideas to the rest of the meeting attendees later in the day.

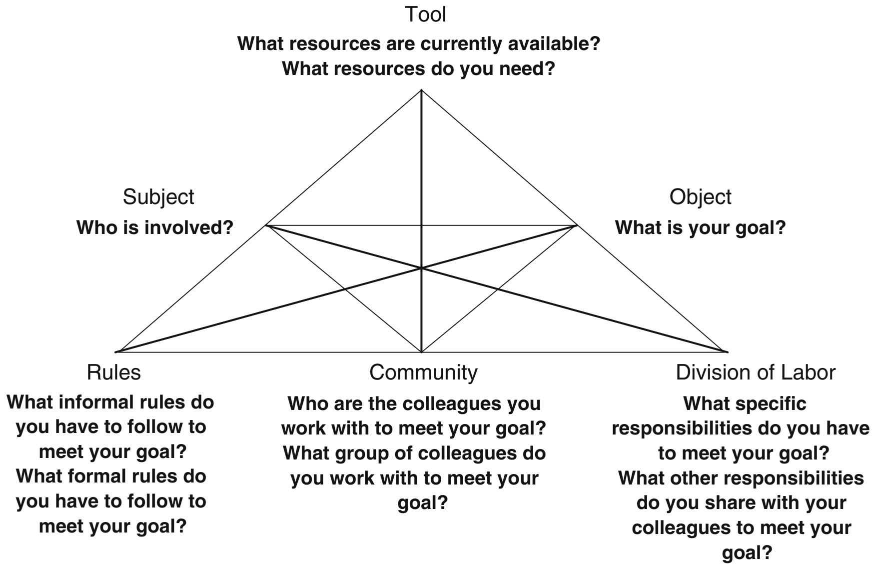

Fig. 6 Instructions for conducting activity systems analysis on K-12 school expectations

K-12 Partnership Expectations Activity Systems Analysis Discussion Question

In your groups, please discuss what you think the K-12 school partnership expectations are. Please use the following graphical model to clarify what to include in the Rules, Community, Division of Labor, and any other areas you feel are important to map out when identifying K-12 partnership expectations. Please indicate any specific conflicts between areas of the model with a squiggly line. While creating the model in your group, please make sure that you take notes to share your ideas to the rest of the meeting attendees later in the day.

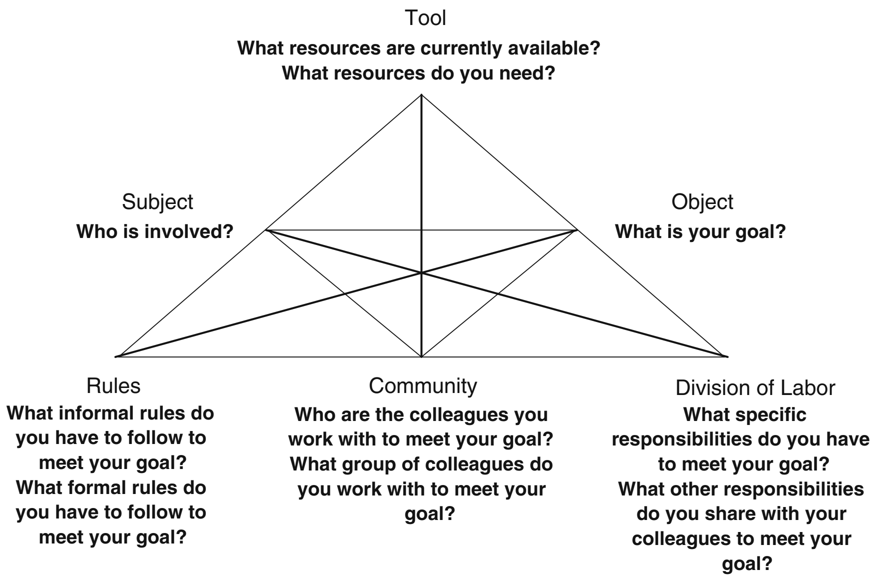

Fig. 7 Instructions for conducting activity systems analysis on university expectations

NIU College of Education Partnership Expectations Activity Systems Analysis Discussion Question

In your groups, please discuss what you think the NIU College of Education partnership expectations are. Please use the following graphical model to clarify what to include in the Rules, Community, Division of Labor, and any other areas you feel are important to map out when identifying NIU College of Education partnership expectations. Please indicate any specific conflicts between areas of the model with a squiggly line. While creating the model in your group, please make sure that you take notes to share your ideas to the rest of the meeting attendees later in the day.

identified strategies to improve relations and ultimately program outcomes. Additionally, all conversations were tape-recorded and transcribed.

Data Analysis of Partnership Activity Systems Analyses Discussion

The two researchers analyzed transcripts from all the discussion and analyses sessions to assess both the practical and theoretical implications from this study. We used the activity systems and group discussion transcripts as primary data sources, and conducted a thematic analysis using the constant comparative method (Strauss & Corbin, 1998). We began this process by both researchers engaging in an iterative process of reading and rereading the transcripts until common thematic units emerged.

We attempted to maintain trustworthiness in this study by (a) obtaining data from multiple sources, (b) involving two investigators in all stages of the study, (c) comparing our investigative process and findings with literature on school–university partnerships and activity theory, (d) obtaining data at different points of time, and (e) obtaining participant feedback on our findings. We triangulated our findings through data triangulation, investigator triangulation, theory triangulation, and methodological triangulation (Denzin, 1989). Finally, there were eight partnership monthly meetings where we were able to conduct member checking.

Follow-Up on Data Reporting and Planning Improvement Strategies

We prepared a one page report, shown in Fig. 8, to present the findings to participants at subsequent monthly liaison meetings and to facilitate member checking. Depending on the specific information we were presenting to liaisons, these member checking sessions ranged from 20 minutes to 5 minutes where participants provided an in-depth feedback or a quick confirmation that we represented district liaison perspectives accurately. The outcomes of these member checking sessions progressively lead to modifications to Fig, 8.

With participants, we jointly examined the common tensions in our partnership relations. We agreed and made a commitment to implement several improvement strategies during the school year. Some of these strategies were already suggested during the activity systems analyses discussion; however, during the follow-up process participants had an opportunity to suggest new strategies.

Follow-Up on Evaluating Improvement Strategies Implementations

At the end of the school year in which we implemented the partnership improvement strategies, participants evaluated changes in partnership activities. During this meeting we provided participants with Fig. 8 to refresh their

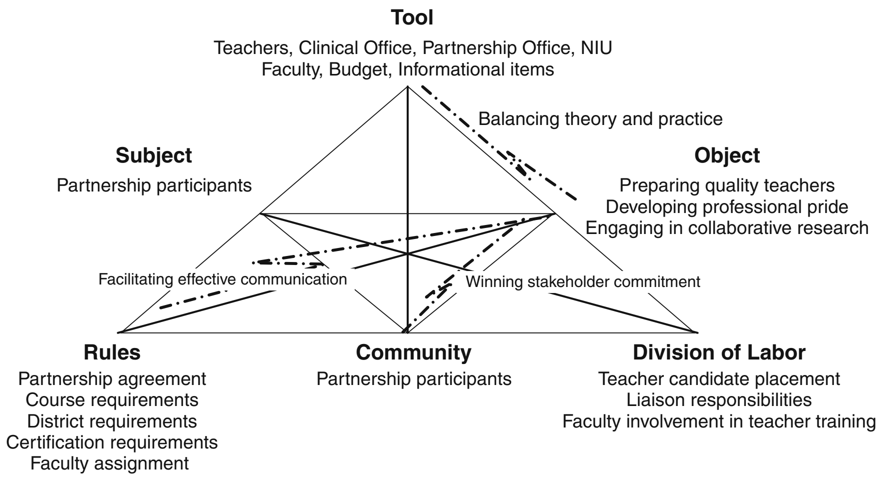

Fig. 8 Reported activity systems analysis results to participants

Partnership Activity Systems Analysis Findings

Identified Tensions

Facilitating Effective Communication

There are communication challenges between NIU and the partnership schools, liaisons and university partnership staff, liaisons and university faculty, among university faculty, and between schools and parents. These areas of difficulties were brought upon by lack of established communication channels that support partnership activities.

Balancing Theory and Practice

Teachers from partnership schools want professional development opportunities that provide them with just in time information regarding new pedagogical techniques based on sound theory. At the same time spending a lot of time on theoretical concepts is not a good use of teacher time. On the other hand, university faculty tend to value more theory and less practice.

Winning Stakeholder Commitment

There is a lack of stakeholder "buy-in" or commitment that makes partnership responsibilities difficult to accomplish. These stakeholders included NIU faculty, preservice teachers, inservice teachers, district administrators, and parents of K-12 students.

memories on the discussions that took place during the activity systems analyses discussions. Participants examined how the improvement strategies that they planed and implemented affected the previously identified institutional tensions, partnership activities, and outcomes.

Improving Methodology

The researchers compiled the theoretical findings from this investigation from the implementation data. These findings are further discussed in the results and implications sections of this chapter. Additionally, valuable comments from anonymous reviewers helped identify strategies to improve future iterations of this study.

Results

Participant Use of Activity Systems Analysis

During our discussion sessions, participants were able to use the activity systems analysis as a guide to frame their discussion topics, and maintain momentum while participating in the discussions. Participants were able to share multiple perspectives on difficult and complicated issues. For example, while identifying partnership goals participants engaged in the following discussion:

Liaison A:	So closer communication between the districts and the [university methods' instructors]. I'd like to see more problem solving involving everyone...
University Staff A:	Is that a rule, is that a...
Liaison A:	I'd like to see it as a rule. I'd like...
University Staff A:	Could you explain it a little more.
Liaison A:	Um, making decisions with...making decisions that both the district and university are collaborating on. More collaboration between how and what methods are taught.
University Staff A:	So are you thinking about preservice curriculum collaboration, then?
Liaison A:	Yes.
University Staff A:	Okay, so that's a goal, then. That's a very good goal.
Liaison B:	Do we come from districts, though, where everyone has the same methods and practices? I mean, I know our methods are very diverse in everything we do.
Liaison C:	We do have the same state standards. And if we're doing a good job, we should be able to meet the state standards. (Partnership Activity Systems Analysis Discussion Group 1, May 13, 2005.)

In the above conversation, participants were able to communicate their frustration regarding the lack of communication between university methods' faculty and teachers. Liaison A shared her perspective on how teachers would like to have a voice in the information that preservice teachers were learning at the university. Liaison B shared her perspective how curricular development collaborations between school districts and the university may be very difficult because every district may have different sets of approved teaching methods. Finally, Liaison C shared her perspective that in a collaborative curriculum development situation perhaps the state standards ought to be the common framework.

There was also discussion on where in the activity systems model certain topics would fit. Initially, facilitating better communication between university faculty and teachers was suggested to be placed as an object or a rule. As the conversation progressed during the retreat, participants agreed that state standards would fit in the rule component. Additionally, communication issues kept appearing as a tension throughout the day.

Fitting a discussion topic accurately in the activity systems model was not an overwhelming concern for participants. However, the model helped them to stay on topic and share multiple perspectives regarding the discussion topics. From the way that discussions progressed, it was evident that participants found it important to exhaust their ideas regarding a topic. As a result, the activity systems that participants constructed were very rich with information. For example, after discussing the K-12 school partnership expectations participants jointly constructed Fig. 9.

Activity Systems Analysis Results

From the qualitative activity systems analysis, we created Fig. 10 as the composite activity system that represents the common themes in the six sets of school district liaison discussion sessions. In the top portion of the triangle, the subject is identified as partnership participants. Liaisons and university staff all acknowledged that the teachers, the college Clinical Placement Office, the college Partnership Office, NIU faculty, the partnership budget, and informational items

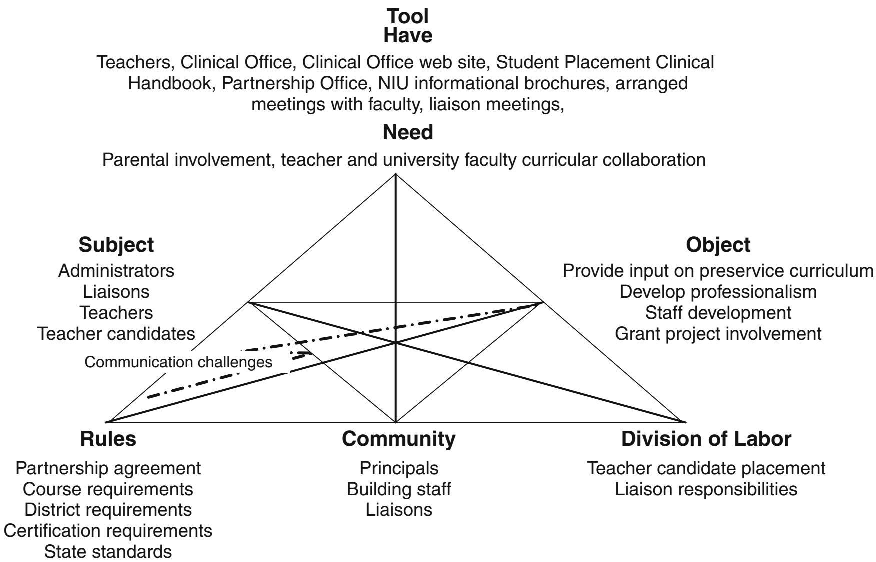

Fig. 9 Participant activity systems representation

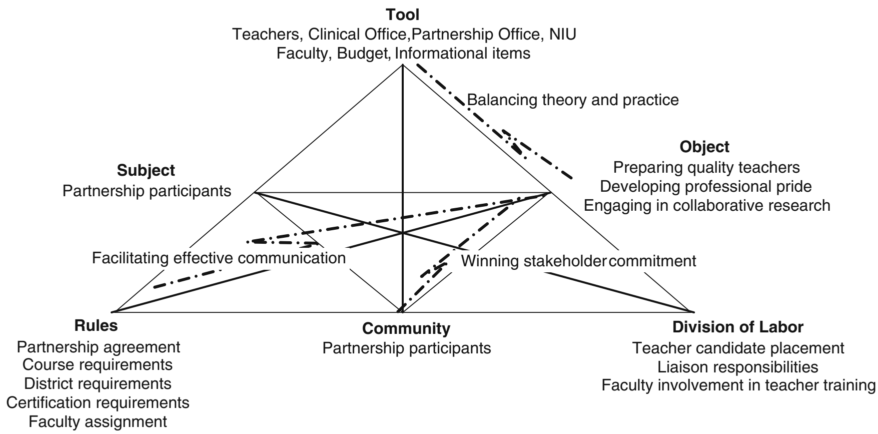

Fig. 10 Activity systems representation of results

regarding the partnership were valuable tools for their work. Liaisons felt that these tools were very strong positive elements of the partnership. In most cases the liaisons were in agreement with the object of the partnership that included preparing quality teachers, developing professional pride, and engaging in collaborative research. Depending on the individual participant, there were varying degrees of commitment to each of the above objects.

The lower portion of the triangle in Fig. 10 represents the rules, community, and division of labor components. The partnership rules were identified by participants as formal agreements and requirements mandated by the university, school districts, and the state of Illinois. These formal agreements shaped how the division of labor was shared among teacher candidates, liaisons, teachers, and faculty. Finally, the community involved the partnership participants.

The tensions that emerged from the analysis of our partnership activities included facilitating effective communication, balancing theory and practice, and winning stakeholder commitment. The tensions reveal the complexities involved in coordinating university and K-12 partnerships. Additionally, the tensions highlight the conflicting goals and expectations that various individuals and institutions have when entering a partnership agreement. Each of the above tensions will be elaborated in the following section.

Tension 1 Initial Findings: Facilitating Effective Communication

According to participants, the lack of communication was the root of several areas of concern in our partnership. This tension involved communication between various partnership members in the subject and community component in Fig. 10 that included university and K-12 schools at the institution level, liaisons and university partnership staff, liaisons and university faculty, among university faculty, and K-12 schools and parents. These areas of difficulties were brought upon by lack of communication channels for stakeholders and key partnership players to be aware of partnership goals and activities in a timely manner. For example, the following excerpt is a response made by two partnership liaisons when the facilitator asked a question regarding partnership communication:

Liaison A: I'd like to see somehow a discussion occur, I don't know if it would be methods' teachers or partnership director, or who it would be, but someone needs to discuss with the principals at the different schools at their SIP program, their School Improvement Programs. If they did that, they could get a real good feel for what they're trying to accomplish with their staff and what they would like to see the preservice teachers, students, accomplish.

Liaison D: Well, that, and it might help find an NIU professor that helps with staff development. (Partnership Activity Systems Analysis Discussion Group 1, May 13, 2005.)

Additionally, teacher liaisons commented that there have been far too many incidents where they were unclear of what they were expected to do. Liaisons indicated that they do not have a comprehensive understanding of the agreements and requirements included in the partnership rules. They also reported that they were unsure of what to tell their school district teachers and principals about what to expect from various partnership activities. This made it difficult for liaisons to effectively participate and assign others in the partnership division of labor.

For example, liaisons felt that they were unclear about what types of activities took place in each of the university's methods' courses in which teacher candidates were enrolled while placed in clinical experiences. The liaisons felt that they would be able to do a better job communicating with cooperating teachers on what types of experiences they ought to be providing to the preservice teachers in their classroom if they were more aware about the methods' courses. This would allow the liaisons to guide the classroom teachers to provide appropriate experiences to preservice teachers that would act as a mediating tool for the students' learning experience.

This was a puzzling finding for the partnership coordinating staff because liaisons have a written contract revised annually that specifies what their roles are, and they attend two to three meetings each semester with the methods' faculty. Through our analysis of discussion data, it became evident that teacher liaisons understood and agreed on partnership goals; however, they were unclear about how to enact those goals into partnership activities and how to determine their own division of labor in various partnership activities. The only task that they were aware of as a major part of their responsibility in the partnership division of labor was to arrange preservice teacher field placements. It became apparent that partnership staff need to assist teacher liaisons to identify specific tasks associated with partnership goals that need to be carried out during the school year. It also became apparent that decisions regarding the partnership at various levels within school districts were made with limited exchange among and between members of the district. Liaisons expressed frustration at not knowing the complete picture of partner activities at the district level.

Tension 1 Follow-Up Findings: Facilitating Effective Communication

During the follow-up meetings teacher liaisons suggested that the partnership office host an annual meeting to bring the school district superintendents and liaisons together and engage in activities designed to facilitate within-district communication. Participants suggested conducting the partnership activity systems analyses discussions with their superintendents. Additionally, participants felt strongly that their superintendents needed to be informed about the tasks they were accomplishing for the partnership.

Tension 2 Initial Findings: Balancing Theory and Practice

Liaisons commented that teachers wanted professional development opportunities that provided them with just-in-time information regarding new pedagogical techniques based on sound theory that would help them attain the object of preparing quality teachers. For example, a teacher liaison shared the following as an example of optimal theory and practice merger activity in the partnership:

Liaison D: Something specific that I would like to see happen is more research being done by the classroom teachers and I'm talking about research lessons and those research lessons could be facilitated by the college professors who could come in and help a team of teachers who, for instance, is trying to figure out a better way of teaching math. Have a math methods teacher come in and help come up with some math methods they could try in their classroom and then those teachers could work with a team on that for a given time, maybe a semester, a year, whatever, and come up with ideas that actually would work and they could meet to figure out what worked, what didn't work. You could have the methods teacher as a facilitator. (Partnership Activity Systems Analysis Discussion Group 1, May 13, 2005.)

Another liaison from a different discussion group commented that recently there had been an increasing number of students diagnosed with Asperger syndrome. She commented that her teachers needed training on research findings on Asperger syndrome and how to adapt their teaching for students with that diagnosis. The same teacher liaison also commented that she felt that spending a lot of time on theoretical concepts was not a good use of teacher time. Clearly, teachers acknowledge the value of theory; however, the need to survive the daily expectations involved in teaching, imposed on them by the rules included in Fig. 10, far outweigh the intellectual exercise of developing an in-depth understanding of theoretical constructs that are the building blocks of pedagogical practices. According to this liaison, teachers tend to want a digest of theory with ample examples of how to manage classroom situations.

This finding indicates the dilemma involved in how to balance theory and practice in partnerships. While teachers want minimal theory and more practice, university faculty tend to value more theory and less practice. In partnerships, universities and schools need to agree on the appropriate balance between theory and practice in their relationship. Perhaps the focus could shift from year to year; however, we have learned that without an agreement on the balance it becomes highly unlikely that both teachers and university faculty will value each other's work involved in preservice teacher preparation and inservice teacher professional development.

Within our partnership the activity that is supposed to provide the opportunity for balancing theory and practice is the district partnership project. As a partnership activity, each district identifies a year-long project that is designed to address a district goal or need. For example, school districts have made agreements with the university to work with faculty to develop curricular materials in specific subject areas, and for faculty to develop a student assessment plan for the district. In the past, these projects have been arranged exclusively through the superintendents' offices. As a result, the project that was intended to serve as a critical tool for mediating the merger between theory and practice did not serve its purpose.

Tension 2 Follow-Up Findings: Balancing Theory and Practice

During the follow-up planning and evaluation meeting teacher liaisons articulated that they wanted to be included in the planning and decision making process for the district partnership projects. They felt that if they were aware of the partnership projects, they could be more successful in identifying and participating in activities for meeting specific theory and practice goals. Liaisons felt that they would be more successful at recruiting other classroom teachers to participate in their district's partnership project and integrate theory to practice if they were informed of the projects. Participants agreed that during the annual superintendent and teacher liaison meetings they would have a discussion regarding their district partnership projects.

Tension 3 Initial Findings: Winning Stakeholder Commitment

Liaisons indicated that a lack of stakeholder "buy-in" or commitment made partnership responsibilities difficult to accomplish. These stakeholders included university faculty, preservice teachers, inservice teachers, district administrators, and parents of K-12 students. For example, as seen in the following excerpt, a couple of the liaisons commented that when parents were not informed about the value of school and university partnerships they contacted the school district to say that they would rather have their child spend time with the classroom teacher rather than a student teacher:

Liaison E: How do we communicate to parents as a partnership? How do we communicate to parents as to what our goals are and what we're doing?

Liaison F: Right, and to really say that it really is a benefit to have the student teachers out. . .there is a benefit, a two-way street. I don't think they see this. They see that their child doesn't have the teacher they wanted, or was supposed to have. Not realizing how much time and effort as teachers we put into the guidance of this person standing in the class. (Partnership Activity Systems Analysis Discussion Group 2, May 13, 2005.)

The liaisons also suggested that there needs to be more commitment to the partnership from methods' faculty at the university. The liaisons felt that this commitment was getting better compared to when the partnership initially started, but there is more room for improvement. The liaisons felt that if the methods' faculty were more forthcoming about what they teach preservice teachers and what they expect from clinical experiences, then the liaisons would be able to find better matches for student placements. Additionally, the liaisons felt that they would be able to add value to the program if methods' faculty were more willing to work with them. Participants ultimately wanted to make a greater contribution in attaining the object of preparing quality teachers and developing professional pride among preservice teachers.

In Fig. 10, the subject and community both consist of various groups of "partnership participants" that are not necessarily well defined. In the current structure of our partnership both committed members and non-committed members are included as subjects and in the community. We also have members of the partnership who become members by default because of rule-driven situations such as teaching assignment at the university and assigned role in school districts. This has created problems when, depending on their degree of commitment to the partnership activities, we have some participants who will go out of their way to facilitate partnership activities and others for whom the partnership activities take minimal importance in their work priority.

Tension 3 Follow-Up Findings: Winning Stakeholder Commitment

During the follow-up planning and evaluation meetings participants suggested the idea to develop a parent brochure to win commitment from one stakeholder group. During the school year, using Partnership Office staff and funds, English and Spanish language versions of a brochure for parents explained the nature of the school–university partnership and the benefits to having university teacher candidates in their children's classroom.

Liaisons took the brochures back to their schools and distributed them. Based on feedback from liaisons during the monthly meetings, these brochures were most welcomed in the elementary grade levels. Teachers in the elementary grades tended to distribute the brochure to all students because parents were very interested in what happened in their child's classroom. Liaisons representing middle school districts reported that their teachers were less concerned about parent perception of the partnership so in some cases only distributed the brochure when a parent requested information about student teachers and the partnership.

Overall Discussion Process Findings

Overall, the methodology allowed school district liaisons to comfortably share their perspectives about partnership activities with very constructive suggestions on how to overcome various tensions in partnership activities. For the first time in our recent partnership efforts, liaisons were able to communicate the complex nature of partnership activities. By isolating the elements that fit into each component of activity systems, participants were able to develop a coherent picture of interactions in their partnership activities.

It was very interesting to find that some liaisons who were less vocal in past meetings were willing to share their ideas during the activity systems analysis discussions. For example, Liaison D who provided her perspectives regarding Tensions 1 and 2 did not actively participate in difficult conversations during our monthly partnership meetings for the past 2 years. The activity systems analyses discussion involved a more comprehensive exchange of multiple perspectives because individuals who were less vocal in past meetings took ownership of the discussion process and contributed to the conversations.

What We Learned

In this investigation, both the methodology development and implementation processes informed one another. The methodology enabled partnership participants to engage in constructive discussions of issues surrounding institutional tensions, which they were not able to do in the past. The implementation and evaluation process of the methods helped participants to work toward overcoming some of the identified tensions.

Practical Implications

Participants had limited knowledge of the theory behind activity systems analysis, but they were able to appreciate its structure. The structure of the modified triangle model helped participants identify sources of conflicts in our partnership while evaluating our activities. The activity systems framework served as a guide for participants to focus conversations on specific topics and discuss improvement strategies rather than being side tracked by placing fault for the difficulties in the school–university relations. Conversations during partner meetings have moved beyond the status quo of listing one complaint after another to strategizing on how to mend the problematic situations.

This methodology provided a more equitable communication process during partnership meetings than the structure we had used in the past. It provided opportunities for less vocal participants to contextualize their ideas within the activity system model and willingly share those ideas. In this process, each teacher liaison was able to take ownership of issues within the partnership and continued to be engaged in the conversations.

After identifying the sources of conflicts in our partnership, this methodology helped participants prioritize improvement strategies. In the past, because we were not able to continue our conversation in a focused and non-confrontational manner, we were not even able to discuss what strategies to develop and implement to resolve partnership conflicts. This methodology assisted partnership members to take actions for improving our relations.

Theoretical Implications

From this study we found that the activity systems model helped participants discuss issues related to individual, institutional, and partnership goals. The activity systems analysis theoretical model included components that helped conduct a thorough evaluation of our partnership relations. It was most useful in identifying the sources of conflicts and evaluating how each component in the activity system model affected the outcomes of partnership activities. Participants were able to follow and use the activity systems model to design future partnership activities and engage in a transformative learning process for redesigning their partnership relations.

The theoretical model itself did not provide any information on how to design future partnership activities or how to prioritize the implementation of relational improvement strategies. Instead, the series of activity system models' participants generated acted as an artifact or a reified object (Wenger, 1998) that captured issues that could not be expressed prior to this study. As a jointly created artifact, the participant activity systems acted as a tool that enabled participants' discussions of difficult issues for planning and implementing future activities that would help resolve tensions in partnership activities.

What We Would Do Differently

During this investigation, we found it very challenging to facilitate a communication process while reconciling the different sets of everyday work-related language used in the university and K-12 school settings. This has been an ongoing challenge in our partnerships. Clarifying this language differences took a lot of our time that was outside of the evaluation activity. In future iterations of this evaluation we need to account for the time necessary for language clarification and perhaps design a specific discussion activity to address this challenge.

There were two critical anonymous reviewer comments we must address. One reviewer commented that our study did not account for the historical nature of activity systems analysis that is well-documented in Cole and Engeström (1993) and Engeström (1987). As researchers of this study, we made a decision to engage participants in the activity systems analysis only once during the one day retreat. Unfortunately, this limited our work to rely on one static snap shot of what participants perceived to be the nature of our partnership activities. Thus, we were unable to capture and discuss the historical developments of changes in participant perception and practice of partnership activities. Another reviewer commented that our data presentation and discussion of results did not reflect the dynamic interaction involved in our participants' activities and the social context that these activities took place. We were unable to sufficiently document these dynamic interactions because we relied too much on the one static activity systems model generated from the one day retreat. The only type of interaction we captured were how participants perceived partnership activity related tensions were bounded by the elements included in the activity systems model in Fig. 10. In future studies, we will engage participants in multiple iterations of partnership activity systems analysis throughout the school year to better portray the historical nature and dynamic interactions in partnership activities.

Finally, we need to engage more partnership participants in future cycles of this study to better capture a comprehensive representation of multiple perspectives. We need to involve school district principals and superintendents, university department chairs and deans, and university faculty to compare and analyze results of their partnership activity systems analysis. The comparison of these results over time will help us build a better understanding of sources of partnership tensions and strategies to overcome them.

Acknowledgments We would like to thank the liaisons who participated in this study to explore our school–university partnership activities. We would also like to thank the anonymous reviewers for providing us with valuable comments that helped improve our work.

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Reflections: Variations on a Theme

Marcy P. Driscoll

"Intro"

I don't usually start chapters that are supposed to reflect on the ideas contained in the other chapters by talking about myself. But in this case, I have to make an exception. My current position, the issues I deal with on a daily basis, the policies that influence my decisions, and those of the people around me. . .all of these color my perceptions. You need to know these things to interpret the opinions I am about to express. You see, I am a dean of a College of Education at a public research university in a state that has arguably the most politicized system of education in the United States.

My path to deaning was probably similar to most who achieve this status. I took my turn as coordinator of my academic program in Instructional Systems and a few years later agreed to serve as chair of my department. This was still turn taking in my mind. I fully expected to return to faculty status after a reasonable period of time of doing my duty for the department. At some point during my 7-year tenure as department chair, however, the landscape shifted. I became interested in broader questions of education policy and began to wonder what those questions might mean for the instructional technology field. During this same period, I was active in the governance of the Association of Educational Communications and Technology (AECT), eventually serving a

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When Editor Les Moller approached me about writing this chapter, I was hesitant. I know the demands of academic writing, and I wasn't sure that my schedule could accommodate the assignment. Les assured me that he would be happy if I wrote what I had said in my dinner remarks at the AECT research symposium on which this volume is based. I agreed to do it. In our subsequent communication, Les suggested a jazz metaphor for the reflection chapters. I have taken him at his word and used some concepts from jazz to organize the flow of my comments. It seemed fitting. As a novice vibraphonist, I look to the great Lionel Hampton for inspiration. For those unfamiliar with jazz, I have included a glossary of terms at the end of the chapter.

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22-month term as President during a time of transition for the organization. Working with media specialists in K-12 schools and administrators of media centers, as well as higher education faculty members, forced me to consider perspectives that were initially foreign to me. How do we find the common ground that will unite us, advance our field, and improve the lives of people?

This broadening of my own perspective continued through an appointment as associate dean and into my current role as dean. As the academic leader of my college, I have to find the common ground across 29 different fields of study, about two-thirds of which deal with preparing teachers and school administrators. As such, I have to pay attention to education policy as it is promulgated by federal and state entities.

One final note and the Intro will be complete. I just ended a 3-year term of service on the School Board for the Florida State University Schools (FSUS). The FSUS is a K-12 developmental research charter school, required by statute to maintain a student population demographic that mirrors the demographics of the state of Florida. Although it is affiliated with the College of Education, the FSUS is a public school run by the School Board, and it operates as an independent school district in the state. Because the school– university–School Board relations are so complex, my role as board member sometimes conflicted with my role as dean. But membership on the School Board has provided me with insights about issues in education that I could never have gained in any other way. And, it made me acutely aware of the power of politics in education.

"Progression"

Chord 1: Education from 30,000 Feet

The contributions to this volume are all in some way about education. Teachers learning to use technology in their instruction (Wise, et al.; Morrison, Ross & Lowther; Strobel & Tillberg-Webb), education reform (Reigeluth, et al.), education and research (Goldman & Dong), scalability of education interventions (Clarke & Dede), and assessing learning in the education system (Spector). All with the hope that our research will make a difference to sustained improvement in learning and teaching in schools. What I find lacking is a sense of the overall education context, the view from 30,000 feet. I know that view primarily from Florida, and because of its size and national stature on education issues, Florida makes a good case in point.

Politics! Politics! Pay for Per-<u>for</u>-mance!

Under the leadership of former Governor Jeb Bush, Florida's education policies have put the state out front and in the news. Bush's A+ accountability plan included the complementary notions of school grading and school choice. He argued that parents should know how well schools are performing and be able to send their children to higher performing schools if they choose.

State officials use standardized achievement test scores and year-to-year gains in student achievement to assign school grades, which are publicized to the community in annual reports. Bush's A++ plan added the idea of pay for performance. Simply put, this means that teachers should be paid more if their teaching leads to higher gains in student achievement.

Affecting school performance, however, is the critical shortage of teachers in the state. Teacher retirements, an amendment limiting class size, and difficult working conditions have all contributed to the problem, which often results in the least experienced teachers being assigned to the most challenging classrooms.

Within this context, the colleges of education at universities around the state are viewed with suspicion. Legislators ask why we cannot prepare more teachers more quickly and at a cheaper cost. To provide a sense of scale, the Florida Department of Education reported the need for 30,000 new teachers for the 2006–2007 academic year, a figure which dropped to around 20,000 for the 2007–2008 academic year. Yet, all of the education colleges in the state combined graduate only about 5,000 new teachers a year. Given this discrepancy, is it any surprise that legislators endorse strategies that give educators heartburn?

Politics! Politics! Pay for Per-for-mance!

The Hoover Institution's Koret Task Force, invited by Governor Bush to assess Florida's education policies, particularly in view of the teacher shortage, concluded in its report that, "Anyone with a bachelor's degree who can demonstrate substantive competence – either by having a college major in the relevant subject or by passing a rigorous test of substantive competence – should be certified to teach in the public schools, subject to background checks" (Peterson, 2006, p. 138). This point made its way into Florida House Speaker Marco Rubio's *100 Innovative Ideas for Florida's Future* (2006) as Idea #20, and he pushed it without success during the 2007 legislative session. However, Idea #16 – "Pay teachers and principals based on performance and merit" – did make it out of the legislature, and the Governor signed it into law. School districts were to submit Merit Award programs for approval by the State Board of Education, but implementation of the mandate has not proceeded smoothly. The bill makes it optional for districts to do performance pay, but if they choose not to, they lose access to funding that can be used for any sort of merit pay increase for teachers.

Politics! Politics! Pay for Per-for-mance!

Chord 2: The Power of Politics

By now, you have figured out that the riff in my tune has to do with the politics of education. Never would I have guessed when I embarked on an academic career that I would become so embroiled in politics. Never would I have believed that I would follow the legislative session so closely or find myself meeting with representatives and senators to lobby for or against particular bills. In his introduction, Spector (Chapter 1) says that education hasn't changed all that much despite investments of research and technology. Actually, I think education has changed a great deal, but not because of us (education researchers or instructional technologists). And not in ways we would necessarily hope to see change.

Schools are far more diverse than ever before. Florida has hugely varied school districts – from urban centers such as Miami, Jacksonville, Orlando, and Tampa to rural, agricultural areas with large migrant populations to coastal regions where housing prices are so high that teachers cannot afford to live there. It has become a minority majority state where the numbers of Hispanic and African–American residents outnumber the once-majority whites. The population of teachers in the state and the profile of the students in our teacher education programs, however, remain largely white. This means that teachers are looking less and less like the students in their classes. Even, according to a recent report by Public Agenda, in suburban schools that are popularly assumed not to be racially integrated (Chronicle of Higher Education, May 21, 2008).

Teachers report more discipline problems and less support from parents in trying to correct misbehavior. On her very first day as an elementary teacher, one of our graduates encountered a parent so angry and out of control that she had to call in police. This was a middle-income school in the suburbs of Jacksonville. Welcome to teaching!

When I meet with superintendents to ask how we might better prepare the new teachers they hire, their first priority is always about classroom management. The second is likely to be about standardized testing and teachers' ability to make sense of, and decisions based on, test scores. The climate created by high-stakes testing and accountability pervades every conversation, every meeting. We must not underestimate the power of politics to drive change. Spector writes that things haven't changed much from the days of "various teachers using different strategies and resources, aiming to achieve quite different things." Yet legislatively conceived state standards mandate a consistency in aims, and the state achievement tests assure that teachers pay attention to the standards.

The State Board of Education in Florida adopted new science standards this spring. A simple vote will result in sweeping changes to how students learn science in this state. Thousand-page science textbooks that present a multitude of topics in factoid fashion will be irrelevant. Assuming the new standards are assessed as planned by the state's comprehensive achievement test, teachers will change their practices. But it remains to be seen whether they employ the evidence-based practices to which Spector refers in his chapter. He cites the high level of agreement among educational researchers about the implications of research for the design of instruction and asks, "Why, then, is there so little application of these findings beyond the involved research groups to improve learning and instruction systemically?" My question is, how do teachers know about these findings? How many instructional designers conduct in-service workshops for teachers? How many instructional design faculty members work hand-in-glove with teacher educators on the curricula that prepare new teachers? How many instructional design researchers publish their findings in teacher practitioner journals? Some, I don't doubt. But I wager not enough.

The robust designs for scalability that Clarke and Dede describe in their chapter (Chapter 3) get us partway there. They recognize the critical role of contextual factors in scaling up educational interventions, and their approach holds promise for helping us to understand what will lead to success of an innovation. They include a comprehensive list of student and teacher variables, technology infrastructure conditions, and school/class variables. But what about policy variables such as an innovation's match to state standards, or a school district's grading/achievement profile? "Essential conditions for success such as student presence and district willingness to implement pose challenges beyond what can be overcome by the best robust-designs" (Clarke & Dede, Chapter 3). Is this an admission that we're not up to these challenges? Could not teams of instructional technologists, education researchers, and teacher educators work in concert to build coalitions with school districts? True collaborations where teacher education programs can benefit as much as school districts from proposed innovations? Where education researchers and instructional technologists can begin to understand the political environment in which schools exist?

"Interlude"

This chapter has gone in a slightly different direction than I anticipated, and I have a few observations about some of the chapters that I don't want to lose. They relate to my overall thesis, but I can't figure out quite how to work them in. So here they are, in no particular order, as a brief interlude, before I return to my primary theme.

I was struck by Wise, et al.'s (Chapter 6) apparent surprise at their finding that teachers' desire to take courses that met their needs and fit their schedule outweighed their interest in working with peers. As long as pay-for-performance plans and statewide standardized testing continue to have political currency, it should come as no surprise that teachers do not value working with peers. There is no system for aggregating teacher performance data to show their collective impact on student learning. This means that, even though the law in Florida allows pay for performance of teacher teams, no district chose to reward teachers in that way. Furthermore, developing a thriving and effective learning community takes time and effort, more than teachers have to devote in the overall context of their jobs.

What Wise et al. illustrate extremely well is a means for affecting teacher practice through well-designed, evidence-based professional development. An important question, though, is whether the learning to teach with technology studio (LTTS) courses are having a broad or cost-effective impact. Despite an inventory of 60 courses, the authors report evaluation studies conducted with small numbers of teachers (107, 20, 59, 13). Overall enrollment was not reported, but one has to wonder why these numbers are not higher. What will it take to scale up?

Goldman and Dong (Chapter 7) suggest that "learning, teaching, and research have never been separate entities, but rather partners within the same education process." I agree that these three entities are not separate, and I would add education policy to the mix, but whether they are truly partners is an open question. Seeking such a partnership, however, is not only a worthy goal, it is also an essential one. I think the authors would agree. They argue a few paragraphs later that "To solve urgent ecological and political problems, researchers, teachers, learners along with all concerned citizens are compelled to engage in issues, share knowledge, and provide access and ensure access of learning resources on a global level."

While I agree with what they say, it takes more. In early May, I attended the National Academies "Convocation on Rising above the Gathering Storm Two Years Later: Accelerating Progress Toward a Brighter Economic Future." If you are unfamiliar with the report, "Rising above the Gathering Storm," it can be found on the National Academies web site (www.nationalacademies.org/cosepup). It was issued in response to the following question, asked by Senators Lamar Alexander and Jeff Bingaman of the Committee on Energy and Natural Resources:

> What are the top 10 actions, in priority order, that federal policy-makers could take to enhance the science and technology enterprise so that the United States can successfully compete, prosper, and be secure in the global community of the 21st century? What strategy, with several concrete steps, could be used to implement each of those actions?
> (Executive Summary, p. 3)

The committee created by the National Academies to respond to this question consisted of members from science, industry, government, and higher education. The committee issued four recommendations focused on K-12 education, research, higher education, and economic policy, and the U.S. Congress acted upon these recommendations by passing the America COMPETES act. The act authorizes programs to improve instruction in mathematics and science and supports funding for basic research in science as well as to attract more people into science majors.

The National Academies held the Convocation this year to gauge progress and determine what steps should be taken next. Participants included scientists and engineers, legislators and federal cabinet members, teachers and higher education administrators. Speech after speech affirmed the consensus of purpose but the lack of progress. Despite its passage, America COMPETES has not been funded. It will take political will in addition to sharing knowledge to solve our most pressing problems.

Goldman and Dong (Chapter 7) offer an intriguing framework for using video-based multimedia tools as a means of facilitating learning and critical thinking. The framework and tools enable students to share perspectives with each other and review and critique their own perspectives. What about using the framework to examine the tools themselves in a reflexive way? That is, what can students learn about *how* the tools facilitate their thinking more deeply, how the tools work to portray a particular perspective? I read this chapter during the week that actor Ben Stein visited Tallahassee to show selected legislators his new movie, *Expelled – No Intelligence Allowed*, which is critical of mainstream science, particularly evolution theory. His appearance in Tallahassee coincided with the public debates occurring over the new science standards, which include the "e"-word for the first time.

The results that Morrison, Ross and Lowther report from their longitudinal study of teachers using computers in the classroom (Chapter 9) reveal both the need for focused teacher training on the technology and the value of taking a global systems perspective to managing the change process. Their results also suggest a need for continued support that will sustain the changes wrought by the technology. They found that the laptop teachers began to "modify the NTeQ approach to suit their teaching style and needs." I had to wonder about the contextual forces in those schools that could be influencing these teachers' behavior. In the face of obstacles such as lack of continued principal support, statewide standardized testing, and dominant school cultures, it is hard for teachers to maintain changes in their instructional practices.

Finally, I read with particular interest the approaches to effecting education reform (or transformation as they call it) that Reigeluth et al. describe in their chapter (Chapter 8). This is particularly relevant to my experience on the FSUS School Board. FSUS is both a school and its own school district for purposes of school grading and accountability. It has a separate elementary, middle, and high school, each with its own principal, and despite one feeding into the other, there is little curriculum integration between grades or across schools. Throughout my tenure on the Board, one of our primary goals was to better articulate the relationship between FSUS and FSU. That is, what are FSU's interests in sponsoring the charter of the school, how should the school and university interact, for what should the university hold the school accountable? There was strong interest on both sides to build a stronger research partnership so that the school could truly serve as a site for innovative curriculum development and evaluation.

As I read and reflected on the Reigeluth et al. chapter, then, I looked for how the models they discuss could be applied to achieve our goals. Unfortunately, I found little practical guidance for how the models might actually work. There is no agency in any of the descriptions. That is, who directs the idealized design process? Who forms the district Leadership Team or School Design Team or Central Support Team? Who is the knowledge work coordinator, or who identifies that person? Who assesses the readiness of the organization to undertake a planned change? Does the School Board serve as the agent to orchestrate the change processes, or does it hire an agent to do it? What is the relation of all these various types of teams to the School Board? Finally, what evidence is there to suggest that these models are effective?

Despite the systems perspective that I brought to the FSUS School Board, I could not figure out how the models described in the Reigeluth et al. chapter would work in my situation. I challenge Reigeluth and his colleagues to take these ideas into the realm of reality, try them out, and then derive explicit procedures that others can follow. If we know how systemic change approaches to K-12 school innovation are supposed to work, then it is up to us to demonstrate it and to provide guidelines that show, explicitly and concretely, how the context and culture of school communities factor in.

"Modulation"

Where do we go from here? What should we do to establish a new key in our song so that the research and development presented in these chapters has the impact that we desire? I suggest that we must become more involved in the politics of education. Our system-wide view must encompass the political system. Politics, after all, is about values. If we want our values to matter, then we must engage in the political process and make sure that our voices are being heard. We must begin to think about how we can influence policy makers.

As we move in this new direction, it is critical that we understand the needs of policy makers and respect the context within which they operate. The following anecdote is illustrative. Almost 2 years ago, I attended a meeting with officials from the Florida Department of Education, Florida Board of Governors, and a representative from the Florida State Board of Education. We were discussing some ideas I had proposed for an innovative teacher education program. To that point in the conversation, I had shared a broad outline of what I had in mind, including unique elements of the program that had research evidence suggesting deeper content knowledge of the program graduates and greater retention once they became teachers. I wanted the support of this group to diverge from state requirements, to develop and implement the program without going through the formal state approval process. While those in the room were generally supportive of my proposal, they wanted to see a bit more detail about the curriculum itself. The State Board representative looked at me and said, "So, can you provide us a draft of the curriculum, let's say, in about a week?"

I have learned that policy makers need information fast. During the legislative session, it is not uncommon to receive a request for information with a deadline to provide it within 2 days. Furthermore, data matter. It is rare to get a request that does not call for data of one kind or another. Often, policy makers want to know output data (how many teachers do we graduate per year, what is the pass rate on the teacher certification exam, what evidence do we have that teacher candidates are skilled in technology). Sometimes the request is process-related, such as what discipline-specific courses are required in teacher education programs. And sometimes, research evidence is sought. Is there a difference in performance and impact on student learning of teachers who have been prepared in teacher certification programs versus those who began teaching and earned certification through some alternative route?

To influence education policy, we should give some thought to what kinds of information will be most helpful to policy makers and how we can become providers of that information. Let me close by suggesting a few ways to begin.

1. Broaden our system perspective to include political variables and study the impact of politics on instructional technology interventions. Even describing the political context will help to inform interpretations of what happened to the intervention and why it worked (or didn't). Systematically accounting for political variables could help to improve the potential impact of an intervention or reform effort.
2. Conduct policy research. I am by no means an expert in policy analysis and research, but according to the Politics of Education Association web site, this would involve "research on the political functions and outcomes of education at all levels, with the final view of contributing to the betterment of society" (www.fsu.edu/~pea/bylaws.html, retrieved May 30, 2008). Policies at the local, state, and national levels have impacts on both processes and outcomes of interest to instructional technologists.
3. Develop and disseminate to policy makers implications of our research for education policy and instructional practice. These should be brief treatises that summarize relevant research findings and clearly state how those findings can be used to improve education. I now send monthly communications to a variety of constituencies (state agency officials, legislators, superintendents) that include Research Briefs. These are one-page summaries of research being conducted by education faculty members at FSU that we hope will make a difference. In fact, the tag line we adopted for all of our public relations materials reads "Research that makes a difference!" Perhaps AECT could support a similar initiative, soliciting research summaries from members and bundling them to send to particular target groups.
4. Cultivate alliances that will strengthen our voice and facilitate access to policy makers. Legislators listen to trusted allies and the people they represent. To become a trusted ally, we must attempt to understand what problems policy makers are trying to solve and ask how we can help them to solve those problems. Once we have asked, however, we must be prepared to deliver, and that means aggregating and providing information quickly, not only anticipating needs but also responding to demands. As members of the electorate, we can meet with legislators and their staffers to provide information about bills under discussion that are of particular interest to us. This requires staying abreast of legislative activity and having a consistent message that we want to relay. The American Association of Colleges of Teacher Education has sponsored for several years a "day on the hill," during which members go to Washington, attend a briefing session, and then meet with their senators and representatives. Last year, the Florida

delegation comprised more than 20 deans, faculty, teachers, and principals who met together with legislative staff to ask for support of the Teach bill, which provides scholarships to students in critical shortage areas of teaching. The individual stories of the teacher and principal who attended had a powerful impact in putting a very personal face on the issues at hand.

Finally, as individuals we can contribute through service to schools and sitting on School Boards. There were certainly meetings during which I wondered what on earth I was doing there, spending time deciding on the cost of school lunches, for example. But the experience will, I believe enhance my effectiveness as an educator and researcher. It is one small way of making a difference, and that's what it's ultimately all about.

Glossary of Jazz Terms

"Intro": A composed section at the beginning of a tune, heard only once
"Progression": A definite series of chords forming a passage with dramatic meaning
"Riff": A relatively simple, catchy repeated phrase
"Interlude": An additional section in a tune
"Modulation": The establishment of a new key

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Reflections: Variation on a Theme: Part 2
Is This Jazz, or Are We Singing the Blues?

Wellesley R. Foshay

Ours is afield of practice, defined more by the complex problems it solves than by the theoretical framework of a particular discipline of inquiry. Like engineers, we pragmatically draw prescriptive principles from many bits of theory, asking only that they contribute a strategy for solving the practical learning and instruction problem at hand. Often, we reason by analogy rather than by direct application of theory. Thus, for example, many in our field would agree that different knowledge types are best taught using different instructional strategies – even though various theoretical reference points often are used for the different knowledge types, and we all don't subscribe to any particular framework of knowledge types, even within the cognitive domain. If our field has an ideology, it is a pragmatic belief that learning and instruction are inherently complex, and thus there is no one best way to do teaching and learning: our goal should be a complex optimization of multiple design choices.

So, is this jazz, or is this singing the blues? The chapters in this volume describe some of the most promising themes of research and theory development in our field. Taken together, they represent big, important changes in most of the design activities in which we engage. Does that mean that, like jazz, we should enthusiastically applaud the inventiveness of each new riff on a familiar theme? Or, does it mean that, like the blues, we should lament what has been lost, by observing the disconnect between the foundations of the field and the work of these authors? Let's examine some major themes which run through the chapters and see whether we see jazz, or the blues. I see three such themes.

1. *We have moved from a process orientation to a design orientation*. It used to be that our faith in process (the systems approach, imported from operations research) was so strong that instructional design (the act of design) and instructional systems development (the process and work flow) were almost synonymous. Now we have largely abandoned the faith in process, in favor of a more contemporary understanding of design (imported by analogy from

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fields such as architecture, engineering, and industrial design). The framework is a layered design approach, and the corresponding work process is non-linear and iterative, emphasizing successive approximation with rapid prototyping and frequent trials. In the current volume, the chapter by Gibbons provides one promising avenue of inquiry on layered design. Goldman's chapter provides an intriguing case example of layered design from another perspective.

2. *We are learning how to connect context with design*. Our early models acknowledged the importance of "system constraints," but there was very little in the literature about how the social/organizational, political, economic contexts in which our solutions must perform should influence our designs. Many chapters in this volume show how context should drive design decisions. Spector's systemic framework provides a great many insights for designers. Strobel and Webb's framework provides another useful perspective on the role of the designer in relationship to the context. Dede's emphasis on sustainable design articulates well with Reigeluth's explication of the strategy options available to us in introducing solutions with technological components into the schools. Morrison's case study provides an example of a model for incorporating context into an intervention strategy for schools. Duffy's powerful case study illustrating the contextual limitations of current social learning theory provides some important insights, and is itself illuminated by the other chapters (particularly Spector's). The point here is that we are finally beginning to develop systematic knowledge of just how, and how much, contextual factors should drive design of solutions, and solution strategies, if they are going to have real and sustained impact. By contrast with approaches to design drawn solely from cognitive learning theory (or, for that matter, from social learning theory taken from constructivist epistemology), the context-based models we are beginning to build make the earlier approaches seem simplistic. Perhaps, as our systematic understanding of the context (or system) matures, we will finally understand why our earlier solutions so often failed to scale or sustain, once they were put into service.

3. *We are learning to deal with the important, not just the interesting*. In the first generation of designs, our learning theory tended to do very well with teaching individual facts, concepts, and procedures using Bloom's Taxonomy of the Cognitive Domain as the framework. Later, we moved to teaching declarative and procedural knowledge structures, building from Gagné's *The Conditions of Learning* through cognitive learning theories such as Anderson's ACT-R. Now we are in the age of complex cognitive learning and expertise. Jonassen's chapter represents a serious attempt to create a structure inside the "black box" of complex cognitive skills and expertise. One could argue that for the first time, if this line of inquiry fulfills its early promise, we will know how to facilitate the learning of important, real-world skills used by master performers in many professions; something which

previously has been considered indefinable, much less unteachable. Perhaps for the first time, we will be dealing with high-value, important cognitive learning outcomes – not some subset of cognitive learning outcomes which we happen to know how to teach.

So, is this jazz, or the blues? Clearly, these chapters point the way to major redefinitions of every aspect of the field – a task which is perhaps overdue, for a field of practice now in its fifth decade. Even the casual reader of these chapters will see the strong influences of current cognitive learning theory, current social change theory, and the emerging discipline of design – signifying a healthy openness to new theoretical perspectives and a continuation of the pragmatic willingness to adapt and apply new knowledge from a wide range of sources. But readers may sing the blues over the abandonment of the familiar tools of the ADDIE process or Bloom's Taxonomy of the Cognitive Domain, and they may view with dismay the independence of this thinking from the particular capabilities of any technology. My reaction, however, leans toward jazz.

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