

Research and Theory in Instructional Systems Technology at Indiana University

Instructional Systems Technology Faculty

Abstract Research and theory-building activities in Instructional Systems Technology at Indiana University revolve around several thematic threads: message design, instructional design/development, technology integration, systemic change in education, and change management and human performance technology. A dozen or more student-faculty research groups are active at any given time on inquiry projects related to these themes. Recent projects, their theoretical bases, and some of their findings are elaborated in this chapter.

Keywords Research · Theory · Faculty · Message design · Systemic change · Instructional design

Overview

Instructional Systems Technology (IST) at Indiana University has long encompassed a large and diverse program, one that often has pushed against the conventional boundaries of the field at the time. However, consistent with its middle name, a “systems” view of the processes of instruction in formal and non-formal settings has for many years dwelt at the heart of the program. This perspective goes back at least to 1969 when the IST label was adopted for what was then a “division” in the School of Education (now a department). The founder of the program, L.C. “Ole” Larson, supported the systems perspective, which had already gained traction at Syracuse University (see Mood, 1964), the University of Southern California (see Silvern, 1963; Heinich, 1965), and Michigan State University (see Barson, 1967). By 1972, the IST curriculum was organized around several emphasis areas: message design, instructional design/development, evaluation and integration, systems design and management, and diffusion/adoption.

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Those themes are echoed in the research-and-theory emphasis areas of IST today: message design, instructional design/development, technology integration, systemic change in education, and change management and human performance technology. The Indiana doctoral program revolves around student participation in research groups working to address these themes. At Indiana, as in many educational technology programs, faculty and students are also often involved in projects to design and develop instructional materials and systems, which are typically evaluated and revised; these might be characterized as “development only” or “primarily development” projects. However, these sorts of activities are not included in this report, focusing instead on research and development work that springs from a theory base and is meant to test and build those theories.

Message Design

Researchers at Indiana University have been in the forefront of inquiry on learning from visuals, exemplified by the early work of Mac Fleming (1967) and Howard Levie (1978). Fleming and Levie also teamed to produce the milestone work on general principles of instructional message design (1978, 1993). The tradition they established is being followed by two current research groups in IST, one working on message design principles for the new digital media, another on instructional illustrations.

Principles of Instructional Message Design for Digital Media

Even as Fleming and Levie were struggling to extract general principles of message design for instructional materials during the decades of the 1960s through the early 1990s (Fleming & Levie, 1978, 1993), media format options were constantly changing and expanding. Message design principles started with the core decisions of how best to present text information and to incorporate images with that text. Soon researchers were adding the complexity of *moving* images with 16 mm films and videos; these media challenged the designer to consider not only the stream of voice narration but to also to couple the moving images i ever changing audio track as well.

Then came hypermedia and the possibility of many unique paths through multimedia information for different learners. The newly popular formats were no longer linear, so the considerations became even more complex. Around this time message design began to fall from Educational Technology curricula, as tools like *HyperCard* and *ToolBook* were embraced as the new “best practices” for format and content delivery. In the mid-1990s the hypermedia formats migrated to delivery by the World Wide Web; its exponential growth vastly increased access to these multimedia information delivery formats and led to further rethinking of message design issues (Misanchuk, Schwier, & Boling, 1999).

New media, different paradigms. Today Robert Appelman’s message design research group in IST is working to establish principles of message design

applicable to the Web 2.0 world—immersive interactive learning environments (IILE) such as games and simulations. The state of the art in these formats surpasses film, video, and hypermedia formats in complexity. In addition, users approach these new media formats with significantly higher level capabilities, not only in interface control, but also in perception and multi-tasking competencies. This places incredible pressure on the message designer to keep up with the levels of sophistication of these new media and their audiences. Nevertheless, even with all these challenges, the goals in message design research are the same as they were when we just had text and pictures to work with. We want to engage the audience with meaningful content, have them be able to perceive the text, images, avatars, music, user interface (UI) elements, and other elements of the “micro-world,” such that they would be congruent in dominance with the message we wish to convey. Researchers are finding that most of the principles from the Fleming and Levie era are still applicable to today’s IILE, for example:

2.3a. Attention is drawn to the parts of a message that stand in contrast to the others. Such contrasts can exist in just about every aspect of the message’s content, organization, and modality (Fleming & Levie, 1993, p. 67.)

Contrast is still vitally important to ensure that salient points—whether in auditory, visual, or verbal forms—stand out.

Building a new paradigm. Before one can derive principles of message design in the new media format of an IILE, one must first be able to define what is happening at any point during the users’ experience, both cognitively, affectively, and functionally. We must be able to compare one user’s experience with another user’s along the same criteria (Appelman, 2005; de Vreede, Verbraeck, & van Eijck, 2003; Garris, Ahlers, & Driskell, 2002; Klabbers, 2000; Reigeluth & Schwartz, 1989; Squire & Barab, 2004). To get at these objectives we have created a Virtual Experience Lab (VX Lab) where we can observe game play, web interactions, and any IILE, be it on a game console or a PC. Through Game Play Analysis methodologies (Appelman, 2007; Zimmermann, Gregory, & Appelman, 2007), we are able to “unpack” the micro interactions and structural changes within the environment on a second-by-second basis. One might think that this level of detail would be over-kill for establishing some broad-based principles for message design, but the pace of interactions and the multiplicity of visual, audio, and functional elements confronting the user are so high, that much would be missed with any other methodology.

Defining the structure of an environment and reporting what happens within it is only a beginning. To design for these new IILEs one must first spend some time learning and playing within them. Thus informed, one can productively begin the instructional design process for an IILE. The path of development (or *pipeline* as it is referred to in the game industry) is an extremely long one, and one that also involves many interdisciplinary collaborators. What we are pursuing is a well defined set of principles to guide teams through the development pipeline for the “serious game.” Many see games and other goal-based scenario activities as a viable format for problem-based learning pedagogies within constructivist paradigms (Appelman,

2008; Barab, Thomas, Dodge, Carteaux, & Tuzun, 2005; Hannafin & Hill, 2005; Jonassen, 1999; J. R. Kirkley, S. E. Kirkley, Myers, Lindsay, & Singer, 2003).

Key attributes of IILEs. With previous message design principles, such as Fleming and Levie's, one finds that the principle posits a relationship between a user's (learner's) perception or experience and a particular structural configuration of the mediated environment, e.g. "attention [user perception] . . . is drawn to parts of the message [a structural element] . . . that contrasts with other elements [the characteristic of the structural element]." The *Experiential Modes Framework* below proposes a typology for message design principles for the new media. It focuses specifically on games and simulations as examples of these new media.

Experiential Modes Framework (EMF)

Player Experience (PX)

1. *Cognition*—encompassing mental activities in both cognitive and affective domains; e.g. the degree of learning as well as the degree of fun, and the "semiotic meaning" of elements.
2. *Metacognition*—encompassing all that the player is aware of: vision, audio, olfactory, kinesthetic, and haptic senses; plus awareness of time, objects, content or information encountered.
3. *Choice*—encompassing the player's perception of degree of control; access to variables and information during game play.
4. *Action*—encompassing the player's perception that they can do things such as: interact with objects, elements within the game, that they have a degree of control; that they have a degree of mobility to move through the virtual environment; that the control interface allows their psychomotor capabilities to effect change.

Game Structure (GS)

1. *Content*—the story, the context, the amount of information available, the degree of concreteness or abstraction of the content, the authenticity, and their variability
2. *Environment*—identifications of the virtual spaces and boundaries, the objects within these spaces and their functionality capabilities, plus any time limits imposed by the game
3. *Formal Characteristics of the Elements*—descriptions of the fidelity, aesthetics, color and audio attributes, and their dominance relative to other elements
4. *Affordances*—encompassing the abilities made available within the game for the player to change, manipulate, and/or to seek alternatives or information

Using this framework one might arrive at a message design principle such as: Interaction [PX-Action] with content [GS-Content] that offers the player multiple options [GS-Affordances] will increase player engagement [PX-Cognition]. Such a framework can be used for developing message design principles for web design, distance education, e-learning, games, simulations, and virtually any IILE.

Instructional Illustrations

A fundamental issue for any study of visual media is a basic theory of picture perception. While there is not a consensus among scholars regarding how images are perceived and used, there are a number of schools of thought that provide frameworks for thinking about and studying these issues. Anglin, Towers, and Levie (1996) provide an overview of theories of picture perception as well as a summary of research on learning from visuals. One of the themes that emerges from this research is that while most people in most cultures recognize objects depicted in pictures (Kennedy, 1994; Sless, 1981), they do not necessarily recognize the meaning intended by the creator of the image. Consistent with the theories of Piaget, some scholars have suggested that young children interpret visual information very literally, and that they may not be developmentally ready to understand abstract concepts or representations included in illustrations (Higgins, 1980; Siegel, 1978 as cited by Cooper, 2002). Furthermore, after analysis of numerous studies on children's uses of visual information, Goldsmith (1984) concluded that emphasis on literal interpretation of visual images could interfere with an individual's ability to generalize to a meaning beyond the specific depiction represented in the given illustration, and that the ability to understand complex visuals is a learned capacity.

Interpretation of visual devices. Elizabeth Boling and her Interface Interest and Research Group (IIRG) have pursued a line of inquiry to discover the extent to which various populations interpret the meaning of simple illustrations including graphical devices consistently with the meaning intended by the designer of the illustrations, and to discover something about how individuals make their interpretations. They found that in some cases images with simple graphical devices in them (e.g., arrows, thought balloons) were interpreted differently from the designer's intention by up to 60% of over 600 viewers in groups that included American elementary school students and adult teachers, and college students in the US, Taiwan and Malaysia (Boling, Sheu, Frick, & Eccarius, 2001; Boling, Smith, Frick, & Sheu, 2003; Boling, Eccarius, Smith, & Frick, 2004; Boling, Smith, Frick, & Eccarius, 2007).

Textbook illustrations. Ongoing studies within IIRG include a survey of the page space devoted to images in textbooks from multiple countries and the interpretation of instructional images in learning contexts, including elementary science classrooms and language learning courses for refugees to the U.S. Results to date indicate that page space devoted to images in science textbooks from elementary through high school range from a low of under 10% in some high school texts to a high

of almost 40% in several first grade texts, underscoring the importance of understanding how these images are interpreted (Boling, Smith, Eccarius, & Rowe, 2005; Smith, Rowe, & Boling, 2005).

Instructional Design/Development

During the 1960s educationists at a number of different R&D centers were experimenting with ways of applying systems theory to instructional planning. Some of the well-known early efforts included Silvern's courses and monographs (1963) at University of Southern California and Barson's (1967) Instructional Systems Development project at Michigan State University. Meanwhile, Gene Faris and Richard Stowe were working along similar lines at Indiana University's Audio-Visual Center (AVC), leading to their Faris-Stowe instructional development model (Faris, 1968). By the early 1970s the systems approach had been incorporated into the faculty consulting operations at the AVC and into the IST (known at that time as Educational Media) curriculum. In the mid-1980s the AVC research group turned its attention away from instructional development (ID) models and toward an examination of ID as a social process (Schwen, Leitzman, Misanchuk, Foshay, & Heitland, 1984). More recently, IST research groups have continued along the line of critically examining the underlying theories and paradigms of ID.

Instructional Design for the Web 2.0: Participatory Learning

During his graduate studies under Prof. Michael Striebel at University of Wisconsin in the late 1980s, Curt Bonk became interested in the various instructional theories and design approaches that emphasized the social aspects of learning, a concept that did not have an accepted umbrella label at the time. Then Allan Collins produced a technical report with John Seely Brown and Paul Duguid for Bolt, Beranek, and Newman on situated learning and the culture of learning (Brown, Collins, & Duguid, 1988), advocating an apprenticeship approach to learning. A later version published in the *Educational Researcher* (Brown, Collins, & Duguid, 1989) aroused great interest among instructional theorists.

Others such as John Bransford and his colleagues at Vanderbilt University were investigating the use of video as a way to anchor instruction or situate it in a real world context (Cognition and Technology Group at Vanderbilt [CTGV], 1990, 1991). Still, it was the work by Brown et al. on *situated cognition* that provided the theoretical perspective to pull together many seemingly disparate strands of research and thinking related to learning in a social context. Somewhat ironically, exactly two decades after this work on situated learning, Brown published an article which argues for another new perspective for learning, namely, *participatory learning* (Brown & Adler, 2008). In it, he argues that the World Wide Web has created a culture wherein learners can build, tinker with, share, and remix ideas and content.

In effect, the Web has moved from a platform for browsing information content with to an interactive learning environment in which anyone can contribute or participate using tools such as wikis, online shared video, learner generated podcasts and blogs, online photo albums, and virtual worlds such as Second Life.

Curt Bonk and his research groups are pursuing Brown's call for research on the types of participatory learning which the Web 2.0 can now provide. Some of their most recent projects:

Wikibook and Wikibookians. Explores collaboration and community building in Wikibook projects between students at Indiana University and the University of Houston as well as an internationally developed Wikibook; entails surveying and interviewing those who have coordinated, edited, or contributed to Wikibooks (Bonk, Lee, Kim, & Lin, 2008, March).

YouTube and other online videos. Explores online motivational and collaborative factors in watching and generating YouTube videos; also examines participatory forms of learning and pedagogical activities (Bonk, 2008, March).

Blogging in higher education in Korea and China. Explores decentralization, augmented socialization, and the pros and cons of blogging in Asian higher education.

Synchronous and asynchronous online learning. Studies the role of the instructor in synchronous and asynchronous learning environments and the types of online moderation and interaction; aims to develop guidelines for synchronous instruction.

Delphi study of collaborative learning in blended learning. The team is conducting a Delphi study of computer-supported collaborative learning in blended learning with 20–30 experts who contributed to *Handbook of Blended Learning* (Bonk & Graham, 2006).

Massive Multiplayer Online Gaming (MMOG) and role-playing game. Explores the educational and training potential of role-playing games and MMOGs; aims to map out a research agenda related to MMOG for the Department of Defense.

Instructional Design Theories and Effectiveness

In addition to Brown's concept of participatory learning, other recent instructional design theories have stimulated research work in IST. In 2002 M. David Merrill proposed a synthesis of several extant theories of instruction, which he called "first principles of instruction." Merrill (2002) claimed that "there will be a decrement in learning and performance when a given instructional program or practice violates or fails to implement one or more of these first principles" (p. 44). One of Ted Frick's research groups has been working on ways to test the validity of Merrill's claim.

In a MAPSAT pattern analysis the team found that when students in 89 different college courses agreed that First Principles occurred *and* they also agreed that they experienced Academic Learning Time (ALT), they were 9 times more likely to report mastery of course objectives, in contrast to when both were reported to be absent (Frick, Chadha, Watson, Wang, & Green, in press). ALT refers to frequent

successful engagement in tasks and activities related to course objectives. ALT is well-documented in the literature as an important variable that predicts student learning achievement.

Chadha, Frick, Watson, Zlatskovksy, and Green (2008) are currently conducting an empirical study of college student ratings of use of First Principles in their classes, their perceived ALT, and their instructors' independent ratings of student mastery of course objectives. Preliminary results indicate that when students agreed that their instructors used First Principles, those students were nearly 3 times as likely to agree that they experienced ALT in the course. Moreover, students who agreed that they experienced ALT were nearly 4 times as likely to be rated as *high masters* of course objectives by their instructors, compared with students who did *not* agree that they experienced ALT. Conversely, students who did *not* agree that they experienced ALT were about 8 times as likely to be rated as *low masters* of course objectives by their instructors, compared with students who did agree that they experienced ALT.

Further studies planned in this research group include a study of teaching and learning quality in Macedonia, and a validation study where classroom observational measures are compared with student teaching and learning quality ratings.

Instructional Theory for Instructional Design/Development

IST researchers have been prominent in building the instructional theories that underlie instructional systems development (ISD). Charles Reigeluth compiled an early synthesis of instructional-design theories (1983), famously known as “the green book.” In it, the developers of those theories summarized the current status of each, and Reigeluth added editor’s notes to point out commonalities across them. Those same authors each developed a lesson based on their respective theories, each addressing the same objectives to facilitate comparison of the theories (Reigeluth, 1987). About a decade later Reigeluth developed a companion to “the green book” series (Reigeluth, 1999) whose purpose was to summarize a broad range of theories that constitute a “new paradigm” of instruction that is customized to learners’ needs and that addresses a much wider range of human learning and development than had traditionally been considered.

Most recently, Reigeluth has been working with a team on another volume in the series, whose purpose is to establish a common knowledge base for instructional-design theory, including a consistent set of terms (Reigeluth & Carr-Chellman, 2009).

Alternative Design Traditions

A team led by Elizabeth Boling and Barbara Bichelmeyer has been studying the ID models used in educational technology in comparison with the “design traditions”

that emanate from fields such as engineering, architecture, graphic design, product design, and software design. They have found conceptual overlaps among these varying design traditions, with ID representing a rather narrow and rigid niche by comparison (Bichelmeyer, Boling, & Gibbons, 2006). They are especially concerned with how design is taught in these different traditions, again finding the teaching of ID to be of questionable scope and rigor, in comparison with other fields. Recently members of Boling's research group have been planning and conducting studies on design thinking and design education, including the use of precedent by expert and experienced designers in several disciplines and development of novice instructional designers as design thinkers in basic ISD courses.

Technology Integration

According to a systemic view of education, the design, development, evaluation, and dissemination of new technology does not constitute a complete process. Hardware, software, and new ways of thinking must be accepted, implemented, and maintained in order to truly become part of the solution. In IST, these activities are subsumed under the umbrella of "technology integration," the focus of a research group led by Thomas Brush, Anne Ottenbreit-Leftwich, and Curt Bonk.

Understanding How Teachers Use Technology

Technology integration, "...the incorporation of technology resources and technology-based practices into the daily routines, work, and management of schools" (Technology in Schools Taskforce, 2003, p. 1), is widely recognized as an essential link in the larger process of K-12 education. Whether teachers integrate technology to enhance students' cognitive and affective development or to help students become better prepared for a global society and economy, effective use of technology has become a critical and expected outcome for students in our schools. Kleiman (2004) proposes that the appropriate uses of technology in K-12 education can "...expand opportunities for students, broaden the information they have available, better connect them with real-world issues and activities, provide them with opportunities for creativity, extend how they communicate and collaborate, and in general, better prepare them for the lives they will lead in the technology-rich 21st century" (p. 248).

The National Educational Technology Plan (U. S. Department of Education, 2004) further supports this notion, detailing the need for students and teachers to become technology savvy in an attempt to maintain an internationally competitive society. Research has indicated that although schools are currently equipped with adequate technological resources, teachers are still not utilizing those resources in their classrooms in a way commensurate with the need (U.S. Department of Education, 2003). The National Educational Technology Plan suggests that "The problem

is not necessarily lack of funds, but lack of adequate training and lack of understanding of how computers can be used to enrich the learning experience” (U.S. DOE, 2004, p. 22).

Preparing Future Teachers to Integrate Technology

Concerns about shortcomings in the meaningful integration of technologies within K-12 schools have led stakeholders at the higher education and governmental levels to place greater emphasis on technology skills for in-service and pre-service teachers. For example, the U.S. Department of Education’s “Preparing Tomorrow’s Teachers to Use Technology” (PT3) program provided grants to teacher education programs to incorporate best practices for preparing teachers to use technology in their classrooms. From its genesis in 1999 until 2003, the PT3 program dedicated over \$750 million to projects focusing on new methods for preparing future teachers to effectively integrate technology into their teaching (Pellegrino, Goldman, Bertenthal, & Lawless, 2007).

Although education and government leaders have promoted the need for better preparation of teachers to integrate technology, and extensive funds have been expended to support these efforts, there is little research examining the actual methods used across teacher education institutions to prepare future teachers to use technology, the impact these methods are having on teaching practices in K-12 settings, and the empirical basis for implementing these methods (Hew & Brush, 2007; Pellegrino et al., 2007; Lawless & Pellegrino, 2007). Recently, researchers have called for renewed efforts in exploring both what knowledge should be taught in pre-service teacher education programs with regard to technology, and how to best prepare teachers to effectively use that knowledge to support student learning. To this point, research that has examined these issues has tended to rely heavily on self-reported survey data and tended to examine how technology was incorporated into teacher education programs at only a superficial “course” level. Finally, there are few detailed cross-institutional studies available that can provide more generalizable implications regarding how to best prepare prospective teachers to effectively use technology.

The technology integration research group focuses on addressing the knowledge gap regarding how teacher education programs prepare teachers to integrate technology into their teaching. They examine experiences related to technology integration included in pre-service teacher education programs and the impact these experiences have on teaching practices in K-12 classrooms. They are currently partnering with the Granato Group in Washington DC on a major research project funded by the U.S. Department of Education’s Office of Educational Technology. The first phase is an overall assessment of the extent to which technologies are being used in American schools. A later phase involves a national study of how teacher preparation programs instruct future teachers on how to best integrate technology for enhanced student learning.

Systemic Change in Education

Advocates of a systems perspective contend that incremental improvements in education systems, such as just adding new media to old classroom structures, seldom lead to dramatically better results. They contend that formal education could be far more efficient, effective, and satisfying if it were designed and managed as a total system, with its interdependent parts aligned according to the goals of the system and educational needs of its communities (See von Bertalanffy, 1968; Banathy, 1968).

Systemic Transformation of Public Education

One of the IST research groups is focused on systemic transformation of public education, in the sense of a fundamental paradigm change. The current paradigm of education was developed for the educational needs and conditions of the Industrial Age and is inadequate for the very different educational needs and conditions of the Information Age. Using systems theory as a guide, Charles Reigeluth and his team have documented that the predominant form of work has changed from manual labor to knowledge work, requiring that many more students be educated to much higher levels and that they be prepared to be lifelong learners, problem solvers, critical thinkers, and team players.

The team also uses systems theory to identify some of the major differences in features for an Information-Age paradigm of education compared to the Industrial-Age paradigm: customization rather than standardization, initiative rather than compliance, diversity rather than uniformity, collaborative relationships rather than adversarial, attainment-based progress rather than time-based, criterion-based assessment rather than norm-based, and a learning-focused system rather than sorting-focused system (Reigeluth, 1992).

However, paradigm change is far more difficult and time-consuming than piecemeal reform, requiring understanding of the systemic change process itself. Thus, the team has been working to advance both descriptive theory (complex causal dynamics) and design theory (means to accomplish desired ends) to help school districts engage in successful paradigm change. Theory building began in the early 1990s (Reigeluth, 1993, 1995), leading to a set of guiding principles: the Guidance System for Transforming Education (GSTE) (Jenlink, Reigeluth, Carr, & Nelson, 1998).

After working with several schools in Indiana, the researchers realized that the school district must be the unit of change, not the individual school, due to strong systemic interrelationships between schools and their district. Thus, in 2001 they began facilitating a district-wide systemic transformation effort in an Indianapolis-area school district, both using and conducting research on the GSTE. Between 2003 and 2006 the group integrated some of the work of Prof. Francis Duffy of Gallaudet University in the GSTE, and in 2006 the group began collaborating with

Duffy to merge their theories into the School System Transformation (SST) Protocol (Duffy & Reigeluth, 2008).

In their work with the school district, the Systemic Change research team has completed seven research studies to improve the SST Protocol (for example, Joseph, 2006; Joseph & Reigeluth, 2005; Lee & Reigeluth, 2007; Pascoe, 2008; Richter & Reigeluth, 2006; Watson & Reigeluth, in press), and has produced an additional 16 conceptual publications about various aspects of this theory (for example, Joseph & Reigeluth, in press; Reigeluth, 2008; Reigeluth, Carr-Chellman, Beabout, & Watson, 2007; Reigeluth & Stinson, 2007a, 2007b, 2007c, 2007d; S. L. Watson, W. R. Watson, & Reigeluth, 2008), with more in progress.

This research group is currently working on a rapid prototyping process to be incorporated into the SST Protocol. The group is dedicated to advancing knowledge about this and other approaches for making the systemic transformation process quicker, easier, and less painful for all people involved.

Simulating Education Systems

Another research group is using systems theory as a foundation for developing computer simulations to teach systems thinking. Axiomatic Theories of Intentional Systems (ATIS), developed by Thompson (2005a, 2005b), has been important for both designing simulations of education systems and for measuring systemic change (MAPSAT, described below). A research group led by Ted Frick has designed and tested a prototype board game called Simulation Game on Technology Integration in Education (*SimTIE*). Under development is a simulation called *SimEd Math: Modeling Differentiated Instruction in Mathematics*. *SimEd Math* and *SimTIE* give preservice teachers the opportunity to select learning activities in a simulated classroom and to experience the consequences of those decisions. Preservice teachers learn to think systemically in order to be successful in the simulations. They must also understand instructional theory to select student learning activities that are most likely to succeed with students in their simulated classroom, based on those students' profiles. To ultimately succeed in the simulation, teachers are challenged to utilize available resources to best individualize instruction that maximizes student learning of mathematics.

Research Methodologies for Systems Issues

The systems perspective demands a different set of inquiry tools than traditional educational research. MAPSAT (Map & Analyze Patterns & Structures Across Time) is a new set of relation mapping and analysis methods. MAPSAT contains two methodologies: Analysis of Patterns in Time (APT) and Analysis of Patterns in Configuration (APC). APT detects *temporal* relations that linear statistical models cannot, nor can Bayesian networks. APC measures *structural* properties that

are determined from axiomatic theory, unlike social network analysis (SNA). APC can measure hypergraphs of multiple affect-relation sets, setting it apart from other forms of network analysis. Both APT and APC have mathematical foundations in graph theory.

Traditional quantitative research methods that are based on algebraic linear models typically yield separate measures of variables, and then researchers statistically analyze relations among measures. That is, they *relate measures*. Alternatively, they could *measure relations* directly. This is not a play on words, but a significant conceptual shift in thinking about research problems and how we collect and analyze data. Frick (1990) invented a procedure called Analysis of Patterns in Time (APT) in order to map temporal relations. Phenomena are observed and coded with categories in classifications. The resulting temporal maps are then queried for temporal sequences of events. The queries are specifications of temporal relations, and the results of such queries then indicate the relative frequency and duration of such observed phenomena. In a study of academic learning time of elementary school children, Frick (1990) found that if interactive instruction was occurring, the likelihood of student engagement was very high ($APT_{prob} = 0.97$). However, when non-interactive instruction was occurring, then students were engaged much less ($APT_{prob} = 0.57$). Regression analysis of the same data was only able to predict 32% of the variance in student engagement.

Thompson's (2008) ATIS Graph Theory provides us a way to measure 17 structural properties of systems, including: compactness, centrality, complexity, flexibility, interdependence, strongness, vulnerability and wholeness. This approach is called Analysis of Patterns in Configurations (APC). A recent study of a Montessori classroom indicated that some structural properties were markedly different in two different types of learning settings: head problems and morning work period. In the latter, for example, there was much more interdependence with respect to affect-relation sets for choice of learning activities and guidance of learning (Koh & Frick, 2007).

Change Management and Human Performance Technology (HPT)

Change Management

In the 1970s vision of IST the “systems design and management” curriculum area embodied the notion that human performance depends very much on arrangements made at the level of the whole organization. New instructional products, new training interventions, and new motivational campaigns would be effective only insofar as they were aligned with and supported by the organization's overall policies and practices. These insights continue to be part of IST's core curriculum, under the heading of “change management.”

Theories supporting change management. In addition to systems theory, theories from psychology have contributed to the change management perspective. Festinger's theory of cognitive dissonance (1957) analyzes the distressing mental state that arises when people find that their beliefs are inconsistent with their actions and the deep-seated need to reduce cognitive dissonance by changing either their actions or their beliefs. In organizations, people need to understand how their actions affect the organization and to believe that it is worthwhile for them to participate in change efforts.

The most wide reaching theoretical contribution comes from the work of B. F. Skinner (1969) and a generation of adherents of reinforcement theory who successfully extended his theories into social psychology and economics. Organizational development is based on the principle that reporting structures, operational processes, and measurement procedures—setting targets, measuring performance, and granting financial and non-financial rewards—must be consistent with the behavior that people are asked to carry out. When an organization's goals for new behavior are reinforced, members are more likely to adopt it consistently.

The sort of behavioral change that is of greatest direct interest to educational technologists is that of accepting and using technological innovations. The psychological processes of how people come to accept or reject new ideas have been explored over four decades by Everett Rogers (1962, 1995, 2003). Rogers considers the main elements in the diffusion of new ideas to be: "(1) an innovation, (2) which is communicated through certain channels, (3) over time, (4) among the members of a social system" (1995, p. 35). He pioneered in analyzing case study data to discern a pattern in the individual's innovation-decision process, finding that an individual passes through the stages of knowledge, persuasion, decision, implementation, and confirmation (1995, p. 36). He also found that individuals played different roles vis-à-vis the spread of innovations—formal leaders, opinion leaders, gatekeepers, and so on. This understanding can enlighten change management work by arranging activities that assist people in moving from earlier to later stages of acceptance, and targeting different people to play different roles in the unfolding drama.

Rogers' theories of diffusion of innovations provided a major theoretical foundation for the "diffusion and adoption" curriculum emphasis area begun at Indiana in 1969. Rogers' and others' theories of change management have continued to inspire R&D activity in IST.

IST research and development in change management. To study the application of Rogers' theory, Ted Frick led a group of students to develop an interactive Web version the *Diffusion Simulation Game (DSG)*, based on the original board version created by Michael Molenda and Patricia Young in the 1970s. In this simulation game users practice applying the strategies derived from diffusion theory, allowing researchers to analyze the efficacy of different strategies. Approximately 3,000 students at Indiana University have played the *DSG* since it went online in 2002. Due to popular demand, a limited version of the *DSG* was made available to the general public in late 2006. Since then, the *DSG* has been played over 4,000 times worldwide at www.indiana.edu/~istdemo. The number of requests for licenses for the full version of the *DSG* has been increasing for use in business and education settings.

Human Performance Technology

A label that overlaps considerably with “change management” but has its own history and theory base is “human performance technology” (HPT). This construct evolved in the mid-1970s out of the work of instructional developers in corporate training, initially guided primarily by B. F. Skinner’s (1969) theories of learning. Joe Harless (1973) found that even after well designed and executed training programs trainees sometimes stopped using the knowledge, skills, or attitudes they supposedly had mastered. In response, he developed a hypothesis that performance was affected by several factors other than learned skills, especially by being given appropriate incentives and tools. Underlying this insight is Kurt Lewin’s “field theory” (1951), which proposes that human behavior is a function of both a person’s activity and the environment in which the activity takes place. In one of the seminal works of HPT, Tom Gilbert (1978) adds “management” to Lewin’s formula, suggesting that the focus should be on the “worth” of activities people perform in organizations.

Thus the concept of HPT is broader than educational technology; it includes educational interventions and also all other sorts of performance improvement interventions, such as incentive programs and provision of better tools. In that sense, it falls outside the conventional boundaries of the department. However, HPT is treated as a *related* concept, one that is highly interconnected with instructional technology when it comes to application in the workplace. Therefore it occupies a substantial place in the curriculum and research agenda of IST.

A research group that includes Barbara Bichelmeyer and James Pershing, recently joined by professors Ray Haynes and Yonjoo Cho, has been involved in a range of R&D activities related to change management and HPT. All, through consulting relationships or other work experiences, have investigated problems of workplace performance in Fortune 500 companies and similar organizations. Bichelmeyer, for example, recently evaluated HPT activities at the Centers for Disease Control and Prevention, after carrying out similar evaluations at Procter & Gamble, Sprint, and the U.S. Coast Guard, among other client organizations. She and fellow research team members recently completed a four-year evaluation study for Cisco Systems (Dennis et al., 2007).

Further, Bichelmeyer and Horvitz (2006) have proposed a conceptual framework, building on the insights of Lewin and Harless, that allows both practitioners and researchers to develop theory-based approaches by using logic models for the design, implementation and evaluation of human performance technology interventions.

Haynes has analyzed business process reengineering within Fortune 500 corporations nationally. He recently applied change management principles and collaboratively developed a competency model to guide the selection, assessment, development, and performance of K-12 principals in the state of Kentucky. Additionally, he recently developed a methodology for evaluating organizational mentoring and succession management programs using the Strategic Collaboration Model (Haynes & Ghosh, 2008).

Meanwhile, Yonjoo Cho previously analyzed, developed, and evaluated numerous performance interventions while serving as senior researcher in the Division of Human Resource Development (HRD) for Korea Telecom (Cho, Park, & Wager, 1999). She is currently engaged in a research project focused on a comparative study of HRD practices in the IT industry in South Korea and India (Cho & McLean, 2008).

Pershing collaborated over a ten-year period with training and HRD managers at the LG Group of Korea to develop and test a model to guide performance improvement interventions, including the design of instruction—the Strategic Impact Model (Molenda & Pershing, 2004). This model-building continued, culminating in another model, the Pershing Performance Improvement Process (Pershing, 2006, p. 15).

Pershing’s research team is currently conducting survey research among HPT experts on the status of and future trends in HPT as part of a larger national project to develop an exemplary curriculum and research agenda for HPT (Pershing, Lee, & Cheng, 2008a, and in press). In two related projects, (1) they surveyed HPT professionals to validate the performance standards established for Certified Performance Technologist (Hale & Pershing, 2008), and (2) they are replicating an earlier study of professional practices and compensation among members of a leading HPT association (Pershing, Cheng, & Foong, 2006, August).

Conclusion

Individually and in teams, faculty and students in IST at Indiana University have been engaged in a wide range of research and development projects stimulated by an array of theoretical and conceptual frameworks. “Systems thinking” provides a conceptual framework for the whole enterprise, but under that umbrella specific programs of research are guided by a number of different theories. Prominent among them are: behaviorist and cognitivist theories of learning and instruction, Gestalt and symbol-systems theories of visual perception, general-systems theory, diffusion of innovations theory, and social-psychological theories of organizational behavior. These theories have generated an abundance of questions, the pursuit of which has led to numerous advances in theory and practice. Through activities such as these, IST intends to maintain its traditional leadership position in building the theoretical structures and the knowledge base in educational technology.

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