My research is focused on how we can optimize learning. By ‘learning’ I mean that the process of coming to know.\(^1\) A process is optimal when it is effective, efficient and appealing.

When a learning process is effective, it means that the learning goals are reached (mastered); when a learning process is efficient, it means that minimal time and other resources are needed to reach the goal; when learning is appealing, it means that the process is interesting and engaging.

Learning can occur by trial-and-error, but this approach is often inefficient and ineffective. Well-designed instruction can improve learning effectiveness, efficiency and appeal.

Instruction can take many forms. Guidance of learning can be very subtle, for example, when a teacher is a coach who provides support (guide on the side), while a student tries to solve a problem that will help him or her achieve the learning goal. Guidance can be very direct, for example, when a teacher demonstrates explicitly what a student is expected to learn and overtly corrects student mistakes when she or he tries to do the learning task.

Education can take many forms as well. Education is more than instruction of students. Education also includes the curriculum or content that students are expected to learn; and education also includes the context of teaching and learning (where it is situated, and other elements of the learning environment)\(^2\).

One of the significant problems faced in formal education today is that students are not motivated to learn. They find many learning activities to be meaningless, irrelevant and uninteresting. For example, in a national survey of 81,499 students in 110 U.S. high schools across 26 states in 2006, researchers found that 9 out of 10 students reported that they were engaged in school learning activities outside of class less than 6 hours per week—less than one hour per day (Yazzie-Mintz, 2007). Furthermore, 2 out of 3 students reported that they were bored in class every day. When asked why they were bored, the top reasons were that learning materials were uninteresting, irrelevant and not challenging enough. Yazzie-Mintz (2007, p. 10) cited one student who stated, “Our school needs to be more challenging. Students fall asleep because the classes aren’t really that interesting.” Another said, “School is easy. But too boring. Harder work or more is not the answer though. More interesting work would be nice.” Why go to school? About 7 out of 10 say, “Because I want to get a degree and go to college.” (p. 4). While 7 out of 10 students overall also agree or strongly agree that they are engaged in school, they apparently “put up” with high school in order to go to college; those who consider dropping out of school indicate that the main reasons are dislike of their school and teachers, and that they do not “see the value in the work they are asked to do” (p. 5).

This problem of lack of student engagement in learning activities is not isolated to high schools. It also occurs in college and universities, as well as in elementary schools (cf. Kuh, Kinzie, Buckley, & Hayek, 2007; Rangel & Berliner, 2007). It is a systemic problem. How can we measure and compare educational systems with respect to their effectiveness, efficiency and appeal?

\(^1\) There are three kinds of knowing: 1) immediate awareness (knowing that-one); 2) knowing how; and 3) knowing that. For further discussion, see: [http://www.indiana.edu/~tedfrick/educologicalFramework.pdf](http://www.indiana.edu/~tedfrick/educologicalFramework.pdf) and Estep (2006): *Self-Organizing Natural Intelligence: Issues of Knowing, Meaning and Complexity*.

\(^2\) For further discussion, see: [Restructuring Education Through Technology](http://www.indiana.edu/~tedfrick/educologicalFramework.pdf) (Frick, 1991).
Furthermore, considerable recent research has indicated that task-centered or problem-centered learning strategies have considerable promise for instructional design (cf., Merrill, 2008; von Merriënboer & Kirschner, 2007; Frick, Chadha, Watson, Wang & Green, in press, 2008). These approaches emphasize that students engage in authentic tasks or problems that are sequenced from simple to complex. Merrill refers to First Principles of Instruction. Von Merriënboer and colleagues refer to the 4C/ID model, e.g., see Ten Steps to Complex Learning: A Systematic Approach to Four-Component Instructional Design (von Merriënboer & Kirschner, 2007). How can we measure and compare instructional approaches such as those suggested by instructional and learning theory espoused by Merrill and von Merriënboer with others such as elaboration theory (Reigeluth, 1999)? Can we measure and compare these instructional approaches in distance education or online-learning settings, traditional classroom instruction, and blended approaches?

There is also considerable recent interest in research in simulations and games for purposes of learning (so-called serious simulations and games, to contrast them with ones for fun and entertainment). A growing number of scholars and researchers are exploring the relationship between simulations/games and learning. Books such as Prensky’s (2001) Digital Game-Based Learning and Johnson’s (2005) Everything Bad is Good for You popularized the notion that games can teach, while Gee’s (2003) What Video Games Have to Teach Us About Learning and Literacy brought academic rigor to the field by examining video games in terms of semiotic domains, situated learning, and identity. Others are exploring how simulations/games motivate and engage (Dickey, 2005; Garris, Ahlers & Driskell, 2002; Paras and Bizzocchi, 2005); how they provide authentic learning experiences (Cannon-Bowers and Bowers, 2008; Galarneau, 2005; Magnusson, 2005; Ruben, 1999); and the relationship between game design and instructional design (Becker, 2005, 2008; Dickey, 2005; Van Eck, 2007). How can we measure and compare various approaches to serious games and simulations with respect to their effectiveness, efficiency and appeal?

Central to the research questions above is: How can we measure and compare processes of instruction and learning with respect to effectiveness, efficiency and appeal?

One very promising and practical way to do this is a new set of temporal and structural mapping methods called MAPSAT.

What is MAPSAT?

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.

In traditional quantitative research methods that are based on algebraic linear models, we typically obtain separate measures of variables, and then we statistically analyze relations among measures. That is, we relate measures. Alternatively, we 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.
I invented a procedure called Analysis of Patterns in Time (APT) in order to map temporal relations (Frick, 1983; 1990; 2006). Phenomena are observed and coded with categories in classifications. The resulting temporal maps are then queried for temporal sequences of events. For example, Frick (1990) found that if interactive instruction was occurring, the likelihood of student engagement was very high (APTprob = 0.97). However, when non-interactive instruction was occurring, then students were engaged much less (APTprob = .57). Regression analysis of the same data was only able to predict 32 percent of the variance in student engagement.

While in APT we map and analyze temporal sequences of events, we can also map configurations of systems. By configuration, I mean system structure—i.e., how components are related or connected to each other. MAPSAT can also be used to map and analyze system structure. Thompson (2005b; 2008) has developed Axiomatic Theories of Intentional Systems (ATIS). ATIS Graph Theory provides us a way to measure 17 structural properties of systems that include strongness, flexibility, interdependence, wholeness and vulnerability 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).

How is MAPSAT different from traditional methods of measurement and analysis? MAPSAT differs from regression methods in that these latter methods assume some kind of mathematical function for modeling a relation. In these traditional methods, variables are measured separately and then statistical association is attempted according to the function assumed (e.g., linear, curvilinear, logistic). In MAPSAT relations themselves are mapped directly, and then later different types of patterns are counted during analysis. MAPSAT is a logical analysis of relations, not a statistical analysis of separate measures.

MAPSAT is a form of network measurement and analysis. More specifically, Bayesian Network Analysis (BNA) and Social Network Analysis (SNA) are similar to MAPSAT in that they are types of network analysis and are grounded in mathematical digraph theory (Thompson, 2008; Jensen & Nielsen, 2007; Brandes & Erlebach, 2005). These three approaches to network analysis are more closely related, compared with extant methods of measurement and regression analysis described above. While MAPSAT APC methods and SNA do have common aims, the advantages of MAPSAT are its theory basis (ATIS) and ability to measure structural properties of hypergraphs of multiple sets of affect-relations.

For an overview of MAPSAT, watch and listen to a presentation by Frick (2007) at http://www.indiana.edu/~tedfrick/PatternsInEducation.html. Also, see the paper presented at the Summer 2008 AECT Research Symposium on MAPSAT: http://www.indiana.edu/~tedfrick/MAPSATsummerAECTsymposiumFinal.pdf.

One practical example of MAPSAT is illustrated in Figure 1 below: Assume that Goals 1 to 5 are important goals for students to achieve that prepare them for careers in science, technology, engineering and mathematics (STEM). Furthermore, notice that these goals are not independent but instead related to each other. For example, Goal 2 is prerequisite and supportive of Goals 3, 4 and 5.

Notice also that the curriculum goal maps for Classroom X and Y are identical, as can be seen in the gray shaded areas in the top part of Figure 1. However, the remaining connectedness in the two classrooms is quite different. Classroom X is more strongly connected than is Y, even though they have identical curriculum goal structures. In the map of Classroom X, more students have mastered objectives in the instructional units, and those units in turn are more connected to the curriculum goal structure—when compared with Classroom Y’s map.
The maps in Figure 1 go beyond what typical curriculum maps represent. Notice that these maps also include instructional units (IUs) that each classroom has completed over a period of 3 months, and the linkages of those IUs to each curriculum goal. For example in Classroom X, note that Goal 1 is supported by IUs A and B, and that Goal 2 is supported by IUs A, B, C and D. Alternatively, in Classroom Y, Goal 1 is not supported by any instructional unit, and Goal 2 is supported by H only. Finally, note how students in each classroom are connected to each instructional unit. A solid line indicates that that student has mastered the learning objectives in the instructional unit, whereas a dashed line indicates partial mastery. No line between a student and an IU means that the student failed to master objectives of that unit.
Research Groups with Frick for Fall 2008 and Spring 2009

**Research Group 1: Investigating Instructional Design for Complex Learning** (CERT group)

This group has investigated use of First Principles of Instruction in college courses over the past 3 years. We have conducted several studies through survey research and course evaluation. For the latest study, see the paper we presented at the 2008 Summer Research Symposium and also this coming November as a Featured Research Presentation at the AECT conference in Orlando: [http://www.indiana.edu/~tedfrick/AECTresearch2008CERT.pdf](http://www.indiana.edu/~tedfrick/AECTresearch2008CERT.pdf).

These past studies have used course evaluations or surveys as a method of collecting data. However, these kinds of data do not lend themselves to help instructors know how to improve their courses. Thus, we will be extending this line of research by attempting to develop specific rubrics for evaluating First Principles of Instruction (Merrill) and for the 4C/ID Model (von Merriënboer). These rubrics will then be converted to classifications and categories that can be used in MAPSAT so that researchers can observe and code instructional and learning events. Through MAPSAT analyses, this will allow us to investigate relationships between those events and learning achievement (i.e., effectiveness of learning). Members of this group will carry out one or more new empirical studies, and submit reports of these studies for publication.

A second focus of this group is to facilitate studies by group members that are in progress, including those by Rajat Chadha and Emilija Zlatkovska. Further studies led by group members will be encouraged and explored.

These studies can occur in online (distance) courses, traditional classrooms, and blended learning settings.

**Current group members:** Rajat Chadha, Zengguan (Clare) Chen, Pamela Green, Miguel Lara, Nathan Powell, Carol Watson, and Emilija Zlatkovska.

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**Research Group 2: Developing and Studying Simulations and Games for Learning** (SimEd Group)

This group wrote several grant proposals in the Spring of 2008. Currently under review is the SimEd-Math proposal to NSF. In 2007, we developed an initial board game version of SimEd-Math, that we called SimTIE. See Figure 2. We conducted play-tests of SimTIE with a small group of preservice teachers and two instructors who teach education technology courses. The prototype they played contained learning activities that were closely connected with standards for elementary mathematics learning that are recommended by the National Council of Teachers of Mathematics (NCTM). The instructors, who were experienced school teachers before becoming professors, were impressed by the decision making required of the players and the fidelity to real world teaching with technology. The preservice teachers reported a greater appreciation for the complexities and practicalities of managing individualized instruction.

While the board game prototype for SimEd-Math shows promise, significant work remains to develop, evaluate, and implement an online version. The computer version will contribute significant improvements that include: 1) easier and quicker play through reduced manual record keeping; 2) more
complex and realistic outcomes through rapid data processing and modeling of system state; 3) instant access to game updates; 4) database tracking of game play and results, to provide learning outcome data and an information base which we can use to apply adaptive learning strategies to make the simulation more dynamic and relevant to each preservice teacher.

A highly significant advantage of SimEd-Math via the Web is that it could be made widely available to preservice teachers everywhere from a central location (e.g., Web servers at Indiana University). I have already led development of a Web-based computer simulation called the Diffusion Simulation Game (DSG) (Frick, Kim, Ludwig & Huang, 2003). The DSG has been played by over 3,000 students at Indiana University during the past 5 years, and a limited version available to the general public has been played more than 4,000 times in the past 17 months. I have also led the design of online learning about plagiarism that has received over 4 million page views in the last 3 years, with over 125,000 students passing the plagiarism test in 2007. We have reason to believe that well-designed and effective Web-based e-learning has great power and reach. We expect SimEd-Math to reach a very wide audience of both preservice teachers (our primary target audience) as well as teachers on the job.

Figure 2. Photographs of the initial SimTIE prototype, May 2007, to be adapted for SimEd-Math.

**Expected activities.** As an initial activity, I will help this group to learn Flex Builder 3 and some ActionScript 3, so that we can build the Diffusion Simulation Game (DSG) in Flex, improving on the limitations of the current production version, which runs in PHP. This will serve two purposes: 1) It will get the group familiar with Flex, which is a powerful development tool for rich Internet applications; and
2) allow the possibility for building in automated data collection using MAPSAT methods in order to conduct research on the DSG.

Next, I will help this group to develop a prototype in Flex and ActionScript of the SimEd-Math simulation. This will serve several purposes. It will allow us to design and build Flex-based tools for making it easier to build serious simulations and games, so that research on these games can be carried out. Most importantly, it will help us to design the Flex-based tools we will need for theoretically-based inference engines—the part of the simulation or game that carries out the rules (or axioms and theorems). Having these augmented tools for developing serious simulations and games will make it easier for others to build their own for purposes of research. We will also build the components that will collect data, again using MAPSAT methods. If the SimEd-Math proposal is funded, then we will have more resources to carry out these activities.

Current group members: Xuan Cai, Miguel Lara, Rod Myers, Kenneth Thompson and Sean York.

Research Group 3: Applying MAPSAT to individual research projects in IST (MAPSAT Group)

The purpose of this research group is to help members learn how to do MAPSAT methods for research, so that they can carry out their own research studies in an area of personal interest. We will review past studies which have used MAPSAT methods. We will do MAPSAT analyses of existing data from current research in progress by members of the group.

The second area of focus is to build Flex- and ActionScript-based tools for facilitating data collection and analysis with MAPSAT. There is overlap with the SimEd Group in this regard. This is intentional. MAPSAT is needed for research on games and simulations such as the Diffusion Simulation Game, SimTIE, and SimEd-Math. We want to build these MAPSAT tools so that they can be incorporated into the simulations and games themselves, as well as be used stand-alone for other kinds of research (e.g., similar to how packages such as SPSS work).

Current group members: Xuan Cai, Rajat Chadha, Zengguan (Clare) Chen, Craig Howard, Miguel Lara, Rod Myers, Kenneth Thompson, and Sean York.
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