**NSF Proposal Submitted to ITEST**

# MAPSAT Curriculum Dashboard: Connecting the dots for STEM Careers

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# Project Summary

The MAPSAT Curriculum Dashboard will help high school students and their parents, teachers and school administrators *see the connectedness* of their curriculum, instruction and student learning to STEM careers (science, technology, engineering and mathematics). This is an I-TEST *Strategies* proposal, since it requires design, development and evaluation of new computer software and training materials to help high school teachers, students and administrative staff learn how to use the Dashboard. Project partners external to Indiana University include Indiana high schools and the Indiana STEM Resource Network.

***Merit***. The MAPSAT Curriculum Dashboard will be a new way to evaluate curriculum maps with respect to their connectedness of 4 kinds of components: 1) students, 2) instructional units, 3) curriculum goals and 4) STEM careers. The Dashboard has the potential to *transform curriculum thinking of educators*. Although existing *curriculum maps* have helped educators evaluate vertical alignment of curriculum with state standards, this concept of alignment is limited. A curriculum map with only vertical alignment will nevertheless be low in strongness, flexibility, interdependence and wholeness. Schools with curriculum maps that are more strong, flexible, interdependent and whole with respect to connectivity of components (types 1 to 4) will better prepare students for STEM careers.

The MAPSAT Dashboard is an innovation based on new methods of measurement of patterns (Map & Analyze Patterns & Structures Across Time). The Dashboard measures proposed here have been derived from mathematical graph theory and general systems theory. Because MAPSAT is new and the proposed software does not currently exist, it must first be developed and tested before implementation can occur. During Year 1 computer software will be developed for the MAPSAT Dashboard. Usability tests and formative evaluation of user interfaces will be conducted with students, teachers and administrators in order to improve the Dashboard design. During Year 2 the Dashboard will be initially pilot-tested and further evaluated in one high school in Indiana that is implementing project-based learning curriculum for STEM career preparation. During Year 3, summative evaluation will consist of a field-test with 3 additional high schools in which project-based learning is being similarly used.

What is unique and very important about the Dashboard itself is that students, teachers, and administrators will be entering data about their curriculum structure that will help them to see how well the “dots are connected.” They will see how instructional units and student learning are connected (or not) to the curriculum map and to STEM careers. The MAPSAT Dashboard in effect provides ongoing feedback to a school, so that it can adjust its curriculum to better prepare students for STEM careers. Similar to an airline pilot who uses a cockpit instrument panel to guide a plane to a safe landing, schools can use the Dashboard to adapt their instructional units to stay on course.

***Impact***. The expected outcomes of the MAPSAT Dashboard Project are to: 1) improve the *relevance* of high school curriculum for STEM careers; 2) improve *student awareness* of knowledge and skills needed for STEM careers; 3) improve the *quality of instructional units* in high school curriculum so that they are *more meaningful* to students and which result in higher levels of successful student engagement; 4) improve the *structure* (i.e., connectedness) of instructional units and curriculum maps in high school with respect to their relatedness to STEM careers.

While the short-term impact of the MAPSAT Dashboard on 4 high schools is important, the potential for long-term impact is to *facilitate the transformation of the curriculum in P-12 schools across the U.S.* One significant barrier to major school improvement is the structure of curriculum itself. Grade levels and textbooks around which the current curriculum is structured have largely been designed with respect to separate subjects—e.g., reading, writing, arithmetic, social studies, health, algebra, biology, etc. While the importance of these areas of learning is not being questioned here, when these subjects are taught and learned in “silos,” the connectivity to real-world problems and career needs in today’s world has gotten lost. It has recently been documented that most high school students are bored in class every day and do not see the relevance of what they are supposed to learn. As teachers improve instructional units so that they are viewed as being connected to real life and subsequent careers, students will see the relevance. This will help motivate those students to make a greater effort to learn. If they make more effort, they are more likely to be more successful in their learning. If these instructional units are connected also to STEM careers, then students will be better prepared for those careers when they graduate.

# Project Description: MAPSAT Curriculum Dashboard: Connecting the dots for STEM Careers

## Overview of I-TEST Strategies Proposal

We propose to create a MAPSAT Dashboard for high schools. This Dashboard will help students and their parents, teachers and school administrators *see the connectedness* of their curriculum, instruction and student learning to STEM careers. We will do this in partnership with the Indianapolis Public School system and the Indiana STEM Resource Network.

During Year 1 we plan to develop the computer software necessary for the MAPSAT Dashboard and to design and conduct usability tests of user interfaces for students, teachers and administrators. During Year 2 we plan to collaborate initially with one high school in Indiana that is building and implementing project-based learning curriculum for STEM career preparation. During Year 3 we would expand the evaluation to include 3 additional high schools in which project-based learning is being similarly used. Although beyond the scope of this proposal, a larger scale longitudinal evaluation of MAPSAT in U.S. high schools is planned for Years 4-6. Our current proposal addresses the 5 requirements for I-TEST Strategies (RFP, p. 9):

First, the potential of our strategy for improving the workforce for STEM careers is well-supported by research on successful student engagement (cf. Kuh, Kinzie, Buckley & Hayek, 2007; Rangel & Berliner, 2007). Increased academic learning time (ALT) is associated with increased student achievement. The MAPSAT Dashboard is expected to increase student ALT. Thus, if high school students spend more time successfully engaged in instructional units related to STEM careers, they will be better prepared for those careers.

Second, our strategy has a built-in design to increase the linkage between STEM and workforce skills. The MAPSAT Dashboard requires school administrative staff and teachers literally *to make links* between the instructional units that students complete and curriculum goals that are in turn connected to STEM careers, as illustrated in Figure 1 below. This will make evident which instructional units have little relationship to curriculum goals connected to STEM careers. In order to increase *strongness* of their linkage structure on the MAPSAT Dashboard, they will need to find or create instructional units which do have more ties.

Third, we plan to implement our strategy in progressive stages, following well-established and effective software design and development procedures. Iterative rapid prototyping that includes usability evaluation with the target audience *throughout the development process* results in incremental improvements that lead to successful products. Moreover, we plan to implement the Dashboard on a small scale initially, conducting formative evaluations, in order to identify and correct implementation problems in an actual high school, before attempting to replicate it in several additional high schools. This method of development and evaluation is very likely to result in a product that will work effectively with high schools in general.

Fourth, the MAPSAT Dashboard is an innovation based on new methods of measurement of patterns (Map & Analyze Patterns & Structures Across Time). Because MAPSAT is new and the proposed software does not currently exist, we must first develop it and test it before any kind of implementation can occur. This is what we propose for Year 1.

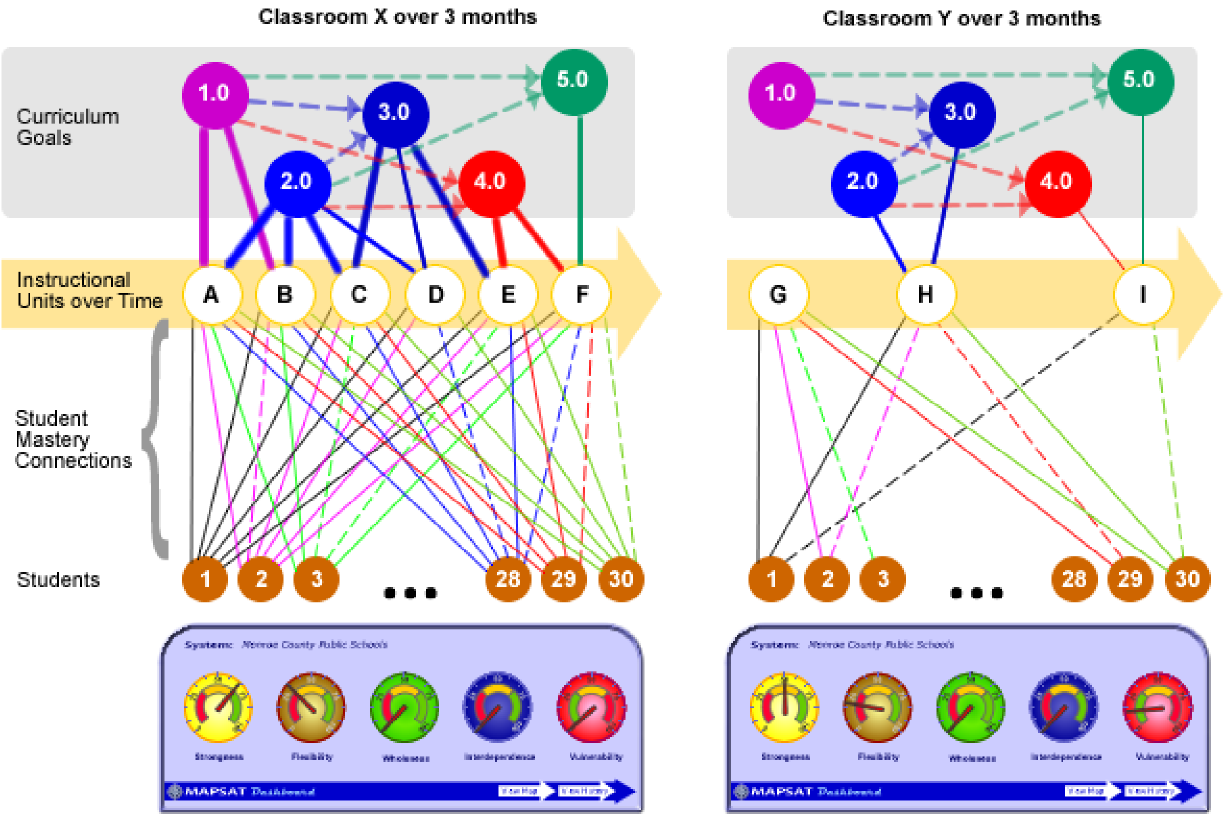
Fifth, the outcomes of the MAPSAT Dashboard Project are to: 1) improve the *relevance* of high school curriculum for STEM careers; 2) improve *student awareness* of knowledge and skills needed for STEM careers; 3) improve the *quality of instructional units* in high school curriculum so that they are *more meaningful* to students and which result in higher levels of successful student engagement; 4) improve the *structure* (i.e., connectedness) of instructional units and curriculum maps in high school with respect to their relatedness to STEM careers. What is unique and very important about the Dashboard itself is that, by using it, students, teachers, and administrators will be entering data that we can use for evaluating these outcomes (as part of our project evaluation). Not only will we be able to see these outcomes, so will high school students, their teachers and school administrators. The MAPSAT Dashboard provides feedback to the school system, so that it can adapt its curriculum to better prepare students for STEM careers. Similar to an airline pilot who uses a cockpit instrument panel to guide the plane to a safe landing, schools can use the Dashboard to adjust instructional units to stay on course.

I created this illustration to show the measurable differences between two classrooms.

### lum Maps for MAPSAT Dashboards

obs (2004) is recognized as a pioneer in curriculum mapping, although this idea has ast 20 years. Figure 1 illustrates how a curriculum map is extended by goals that are to instructional units, and indirectly to students. Assume that Goals 1 to 5 are tudents to achieve that prepare them for STEM careers in science, technology, engineering and mathematics. 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.

**Figure 1. Maps of Two Different Classrooms, X and Y, and their MAPSAT Dashboards**



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.

If those curriculum goal structures are designed to help prepare high school students for STEM careers, then *the MAPSAT Curriculum Dashboard provides metrics about the connectivity of classroom instruction and student learning to those STEM-related goals.* Structures that have greater strongness, flexibility, interdependence and wholeness and with less vulnerability will better prepare students for STEM careers. The MAPSAT Dashboard will provide indicators of the effectiveness of STEM career preparation in a high school by measuring the *structure* of its curriculum, instruction and student learning.

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.

The maps depicted in Figure 1 are student-instructional unit-curriculum (S-IU-C) maps. It should be immediately apparent that *the S-IU-C map for Classroom X is much more connected than that of Classroom Y*. It is evident in Figure 1 that students are being less well prepared for STEM professions in Classroom *Y*. The instructional units (IUs) in which students engage are *not* well-connected to STEM goals in *Y*; in fact IU *G* is not connected to any STEM goal. On the other hand, there are many more connections between instructional units and STEM goals in Classroom *X*.

I created this concept design of the MAPSAT dashboard.

*The MAPSAT Dashboard.* Imagine for a moment that a school has an electronic dashboard that shows [illegible] of properties of their S-IU-C maps for all classrooms and students in the school. Similar to how classrooms are represented in Figure 1, maps for an entire school could be measured. School [illegible], teachers, students and their parents could "see" how their school is doing at any time. A [illegible] dashboard is analogous to the cockpit instrument panel that a pilot uses to fly an airplane. The instrument panel tells the pilot about important indicators such as the plane's heading, airspeed, and status of landing gear.

**Figure 2. Prototype MAPSAT Dashboard for High Schools**

This idea of a school or classroom dashboard is not as far-fetched as it might initially sound. A research team in the School of Education at Indiana University has been developing ways to measure temporal and structural relationships among parts of a system. These methods are called MAPSAT: Map & Analyze Patterns & Structures Across Time. We have developed computer software that can measure structural properties of systems—i.e., how the parts are related (Frick, Myers & York 2008). We can measure the strongness, flexibility, wholeness, interdependence and vulnerability of structural relationships (Thompson, 2008).

A high school can use a computerized S-IU-C map, similar to those depicted in Figure 1, as a shared electronic diary that is a web of students and their mastery of specific instructional units (IUs), and the connections of those IUs to curriculum goals that are related to STEM careers.

But how do schools get a "handle" on a very large map? Is there a way that such maps can be assessed with respect to the nature of their connectivity? For example, how can they tell if one map is more flexible than another? The MAPSAT Dashboard will provide this information.

Flexibility as a property of a map pertains to components that are connected *to* by two or more other components. Notice in Figure 1 that Goal 2 is supported by 4 different instructional units (IUs *A*-*D*) in Classroom *X*, but only by one IU in Classroom *Y*. When an entire map is considered, the measure of overall flexibility in the map can be obtained by having the MAPSAT computer software count paths to components that have more than one connection to them. Practically speaking, what this means, for example, is that if one instructional unit is not successful in helping a given student to reach a particular goal, then other units are available as alternatives. On the other hand, consider what might happen if there is little or no flexibility. If only one instructional unit is provided to help students to achieve each curriculum goal, then there is no flexibility in the curriculum structure and students will be less well-prepared for STEM careers.

Measuring structural properties of maps, such as flexibility, would become extremely onerous for very large maps with literally thousands of components and hundreds of thousands of connections. The MAPSAT Dashboard will do this counting much faster and more accurately than doing it by hand. Furthermore, the MAPSAT Dashboard will allow students, teachers and administrators to easily use their Web browsers at various times during the school year to securely enter data into a centralized location where these maps are electronically stored in a computer database so that such analysis can be done.

## Benefits of MAPSAT Dashboards for STEM Careers

MAPSAT maps can be used by high schools in three important ways:

*Planning the curriculum and instruction.* The MAPSAT software will give administrators and teachers ways to visualize and to measure how their specific instructional units address curriculum goals that prepare students for STEM careers. This will enable them to see, for example, curriculum goals that are not well supported by instruction, and how designing and implementing instruction to address those gaps will increase connectivity and resulting structural measures of that connectivity.

*Counseling students with their MAPSAT "report cards."* For counseling purposes, an individual student's curriculum map will show the progressive connectivity of that student's learning to curriculum goals that are supportive of STEM careers. From a student's perspective and that of his or her parents or guardians, the continually updated MAPSAT map for *that* particular student will show how well he or she is being prepared for STEM careers as she or he heads toward graduation from high school. Such a map will be a very useful kind of electronic "report card" to show that student's cumulative progress while in school, much like a road map is initially used to plan a car trip and then subsequently used to gauge progress toward the chosen destination.

*Adjusting the student-instructional unit-curriculum (S-IU-C) map "in flight."* While standardized tests indicate levels of student achievement in academic subjects, these test scores do not tell us how to make adjustments that will improve the curriculum. While standardized test scores provide measures of student learning achievement, they are not enough. As an analogy, consider an airline pilot who is trying to land a plane in a dense fog. We will know whether the plane lands on the runway or crashes—analogous to whether or not schools make Adequate Yearly Progress (AYP) according to *No Child Left Behind* criteria (NCLB).

If the pilot is flying blind in the fog without an instrument panel, she or he has no idea where the plane is going to land. An instrument panel is required. Air speed, engine thrust, altitude, ground speed, rotation, position and extension of wing flaps, and angle and rate of descent are also critical. The pilot uses a number of different cockpit instrument readings in order to safely land the plane—in addition to visually aligning the plane with the runway as the plane gets close.

Changing the curriculum without ongoing measurement is analogous to the pilot flying blindly in a fog. Without an instrument panel to gauge progress, the likelihood of landing on the runway is guesswork. Likewise, attempts to change curriculum will be guesswork without adjustments based on valid measures. The MAPSAT Curriculum Dashboard will help schools see whether adjustments they make in curriculum and instruction are keeping them on course.

## Need for MAPSAT Dashboards

People today would not fly in a commercial airplane without a cockpit instrument panel, which lacked communications with air traffic controllers, and which was not flown by highly skilled pilots. Yet most American schools operate in a manner analogous to airplanes flying in a fog without cockpit instrument panels while trying to land.

What schools need is *ongoing measurement that matters*. We propose to develop a new system of measurement to help schools do this: the MAPSAT Curriculum Dashboard. The Dashboard will summarize critical indicators about what is happening in a school. The Dashboard will be a window into a detailed computerized map that shows *linkages* of 1) individual students to 2) instructional units to 3) curriculum goals for STEM careers.

Measures of student-instructional unit-curriculum (S-IU-C) *structure* will be the critical indicators on the Dashboard for a school to use. The Dashboard will provide structural property values that will help schools know how well they are linking student mastery of instructional units to curriculum maps that in turn support STEM careers.

For example, in Figure 1, it can be seen that Classroom *X* is both stronger and more flexible than Classroom *Y* over the same time periods with the same curriculum goal structures. Notice that in Classroom *Y* the instructional units are less connected to curriculum goals, and students have fewer mastery connections to instructional activities. Classroom *Y* is more vulnerable than X. These maps are updated over time as students complete various instructional units. MAPSAT will calculate changes in structural property values of these evolving maps. Those values in turn will be displayed on the Dashboard as system structural changes occur.

## 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.

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. 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.

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. Space does not permit a complete, detailed comparison here.

## Measuring Teaching and Learning Quality of Instructional Units

We assume that teachers will be assessing student mastery of learning objectives in each instructional unit by evaluating student performance and entering grades into a grade book as they normally would do. This will allow the MAPSAT Dashboard to assign a weight to each connection between an individual student and each instructional unit when it is completed. An instructional unit is expected to be a student project, chapters in a textbook, etc. that would take several weeks to complete.

However, how do we determine the path weights between specific instructional units and the curriculum goals to which they are connected? We propose to do so by having *students* rate the quality of each instructional unit by use of *Teaching and Learning Quality Rating Scales* (TALQ Scales) described below. Students will independently rate each unit of instruction after it is completed by taking a 5-minute Web survey on a computer connected to the Internet. Student ratings will be pooled by the MAPSAT Dashboard over time. Students will not be able to rate a unit until their teacher has graded their performance. A student will not be able to see his or her grade until *after* she or he rates the unit. Thus, the teacher grades the student, and the student "grades" the unit of instruction.

On the other hand, teachers will be making the connection(s) between each instructional unit and the curriculum goal(s) that it supports. Those teacher-made connections in turn are "amplified" by the average student ratings of that instructional unit. A unit will get higher average ratings according to its engagement qualities and incorporation of First Principles of Instruction, as perceived by students. Note that the teacher makes the judgment about the appropriateness of each instructional unit for its support of curriculum goals, not the student.

Two areas of research on classroom quality that are supported by research are: 1) Academic Learning Time (ALT) and 2) First Principles of Instruction.

Rangel and Berliner (2007) define ALT as "…the amount of time that students spend on rigorous tasks at the appropriate level of difficulty for them" (p. 1) when those students are "… engaged in tasks relevant to curriculum expectations and assessments" (p. 1). That is, those tasks need to be in a student's zone of proximal development (Vygotsky, 1978), which means that the tasks cannot be done by a student alone but can with assistance or guidance, and that those tasks are sequenced to lead towards curriculum goals, not just repeatedly doing the same tasks successfully. Numerous studies have found significant positive correlations between ALT and student achievement (cf. Kuh *et al.*, 2007; Berliner, 1990; Brown & Saks, 1986).

First Principles of Instruction were synthesized from extant theories of instruction (Merrill, 2002; Merrill, Barclay & Schaak 2008). One or more of these principles were observed to occur in all of these theories, although the names of these principles may differ. 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):

1) A series of simple-to-complex *real-world problems* (authentic whole tasks) in which students engage;

2) *Activation* of student learning so that students connect what is to be newly learned with what they already know or can do;

3) *Demonstration* of knowledge and/or skills that students are expected to learn;

4) *Application* of what students have newly learned, so they are able to try it out with instructor guidance and feedback as needed; and

5) *Integration* of what is newly learned for use in students' personal lives.

In a MAPSAT APT pattern analysis, Frick, Chadha, Watson, Wang & Green (2007, in press) found that when students in 89 different college courses agreed that First Principles occurred *and* they also agreed that they experienced ALT, they were 9 times more likely to report mastery of course objectives, in contrast to when both were reported to be absent. Chadha, Frick, Watson, Zlatskovsky 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 (*n*=190 students) 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 8.5 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.

We believe that First Principles of Instruction and Academic Learning Time hold considerable promise for measures of quality of instructional units. We propose that students who participate in a specific instructional unit will independently rate it, using a modified version of the TALQ instrument from Frick *et al.* (2007, in press). Sample items in this modified TALQ are listed below. For each statement, the student selects either: strongly agree, agree, undecided, disagree, or strongly disagree (Likert rating).

*Sample items for authentic problems/tasks*: a) The tasks or problems in this instructional unit are similar to what people do in real life. b) I see how tasks in this unit are similar to what a scientist, engineer or information technologist does. c) The tasks in this instructional unit help students prepare for a career in science, technology, engineering or mathematics.

*Sample items for activation*: a) I was able to connect my past experience with what I learned in this instructional unit. b) My teacher helped me make connections between what I already knew and new knowledge and skills that I learned in this unit.

*Sample items for demonstration*: a) My teacher showed me what I was supposed to learn or do in this instructional unit. b) I saw examples of what I was expected to learn in this unit of instruction.

*Sample items for application*: a) When I was doing tasks in this instructional unit my teacher helped me when I needed it. b) My teacher gave me feedback on how well I was doing the work in this instructional unit. c) If I made a mistake in my work in this unit, I learned how to correct it and do it right.

*Sample items for integration:* a) I see how I can use what I learned in this unit of instruction to my own personal life. b) I was able to show and tell other people what I learned in this unit.

*Sample items for academic learning time*: a) I think that I did really well in this instructional unit. b) I spent a lot of time and effort to do good work in this unit. c) I believe I was very successful in doing the tasks and problems in this instructional unit.

Scale scores from each student will be averaged for each instructional unit. Then a composite score will be computed from those averages. The value of that score will then serve as a weight for the connection between that instructional unit and each curriculum goal it is connected to. For example, if student Academic Learning Time and the presence of First Principles of Instruction for that unit are rated highly, then the weight of that activity is greater (as depicted by thicker lines between that IU and goals in Figure 1, e.g., between unit *A* and Goals 1 and 2). These weights, in turn, will be used in calculation of MAPSAT structural property measures, similar to how the weights of students are connected to instructional units (i.e., from teacher assessment of student performance in their grade books) are similarly utilized in calculations of structural properties of the map. Alternatively, instructional units that are rated as lower in quality by students will result in smaller weights for connections to curriculum goals. Measures of some structural property values, e.g., for strongness, will be affected by these path weights accordingly.

Safeguards will need to be built into the MAPSAT Dashboard in order to minimize abuse and unauthorized access. Students, teachers and administrative staff will need to login to the Dashboard. Thus, the MAPSAT database must contain an up-to-date list of valid users. Whenever new data is entered into the system, it will be tagged by the username, for purposes of accountability. Teachers will select or create instructional units and link them to curriculum goals that are supported by those units. Furthermore, teachers will be grading student performance in an instructional unit, and so a student is linked to that unit by virtue of his or her grade or score. A student can rate an instructional unit only once to which he or she is linked. Students will not be able to see their grades for a unit until *after* their ratings are submitted. Students will not be able to see other student ratings, and teachers will only see average ratings of each unit, not those from individual students. Ratings of instructional units should be used for the purpose of improving those units or to find better ones to replace units that, over time, are not working very well with students—in concert with the professional judgment of teachers and curriculum specialists. The goal is to try to create a win-win situation.

### MAPSAT Addresses the Problem of Lack of Student Motivation

We realize that having students evaluate instructional units is not commonly done in high schools. Nonetheless, there are major problems of student motivation to learn in U.S. high schools. This is well documented, for example, by a survey of 81,499 students in 110 high schools across 26 states in 2006, where researchers found that 2 out of 3 students reported that they were bored in class every day (Yazzie-Mintz, 2007). 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." Furthermore, those students 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).

The ARCS model identifies critical factors for motivating students to learn: <u>a</u>ttention, <u>r</u>elevance, <u>c</u>onfidence and <u>s</u>atisfaction (Keller, 2001). The modified TALQ scales used in the MAPSAT Dashboard calculations address these motivational factors. The TALQ authentic problems scale and the student integration scale address the issue of *relevance*. *Attention* is addressed by the TALQ academic learning time scale. Finally, empirical research by Frick *et al.* (2007, in press) has indicated that when students agree that First Principals of Instruction occur *and* they agree that they experienced academic learning time (successful engagement), *they are 3.6 times more likely to be <u>satisfied</u>* with a course, compared with the reported absence of First Principals and ALT. Student *confidence* would be expected to increase as students try out what they have learned with teacher guidance and incorporate it into their lives (TALQ application and integration scales).

In summary, asking high school students to rate instructional units with the modified TALQ scales, as we propose to do for the MAPSAT Dashboard project, will provide empirical evidence to teachers and schools about what instructional activities are motivating to students because they are relevant and meaningful. To be blunt, much of the curriculum in today's high schools is boring to students. There is ample evidence to support this. The curriculum must be changed so that it is more relevant and meaningful to students. Thus, the MAPSAT Dashboard reveals motivating aspect of schools' present curricula through TALQ ratings, allowing schools to adjust for optimal success.

### Research and Evaluation Questions

*Year 1 MAPSAT Dashboard Software Development:* Are students, teachers and administrators in the pilot high school: 1) Able to use the MAPSAT software prototype interfaces easily? 2) Do they understand the MAPSAT Dashboard maps and measures used? 3) How can the MAPSAT Dashboard be improved? 4) What are the reliabilities of the modified TALQ scales (Teaching and Learning Quality) for use by high school students?

*Year 2 MAPSAT Dashboard Pilot Test in One High School:* 1) When, how much and why do students, teachers and administrators use the MAPSAT software in the pilot school? 2) Does the school-instructional unit-curriculum (S-IU-C) map increase during the school year with respect to the following structural properties: strongness, flexibility, interdependence and wholeness? Does S-IU-C vulnerability decrease? 3) What is the change in awareness, self-efficacy and attitudes of students with respect to knowledge and skills needed for STEM Careers?

*Year 3 MAPSAT Dashboard Field Test in Four High Schools:* The same questions will be addressed as in Year 2, only the evaluation will be expanded to four high schools.

**Project Plan Year 1**

The first year will be focused on MAPSAT software development and formative evaluation in one school in the Pathways Initiative between the Indiana University School of Education and partner schools (most likely Manual High School in Indianapolis, IN). We will use an iterative rapid prototyping, user testing, and revision cycle. This is an efficient and effective development method (Frick, Su & An, 2005; Dumas & Redish, 1999; Nielsen, 2000, Snyder, 2003; Tripp & Bichelmeyer, 1990). This process consists of the following phases: a) needs assessment of stakeholders; b) rapid prototyping on paper and usability evaluation with target users to identify design problems and fix them; c) rapid prototyping on computer and further usability testing with target users to identify design problems and fix them; d) building the production version of the software system; e) maintenance and refinements of the system (Frick, Su & An, 2005, p. 21).

For software development, we will need to do the following tasks: While we already have a preliminary version of the MAPSAT software for structural property value algorithms, we need to develop the database that will be used by schools. We plan to do this in MySQL on a Linux server, because both are free and widely used worldwide for database applications. The database is where the following are stored: curriculum map, instructional unit descriptions, lists of participating teachers and students in the high school, student ratings of instructional units, and most importantly the connections that exist between components.

In addition, the database must be structured so that appropriate levels of privacy and security of data are maintained. Thus, there will need to be authentication so that a student can only see data appropriate to him or her. A teacher should be able to see all the students that he or she teaches, instructional units used, the curriculum map, and all the relevant connections among those components. A principal should be able to see all the student and teacher data in that high school, but not other schools. The superintendent of the school district should be able to see all student, teacher and school data in that district. The public could be allowed to see *structural measures* of district or school maps, but not parts of maps that include individual student and teacher data.

The MAPSAT Dashboard will rely on the Internet connectivity and Web browsers for users to access the Dashboard and its functions, providing that they are authenticated as described above. This means that each user will have a username and password to login. Then users will interact with the Dashboard through Web browser interfaces that we design and provide. We plan to develop these interfaces in Flash ActionScript, Flex Builder, PHP and JavaScript. This will allow the Web interface to seem like an interactive application (e.g., e-mail, word processing) rather than a sequence of Web pages.

We have found it very useful to initially create paper prototypes and to conduct usability tests with the target audience (cf. Frick, Su & An, 2005). This actually speeds up the development process, by simulating the interface on paper initially. What is critical in these usability tests is to have users do authentic tasks, listen to them think-aloud, and observe them without helping. Problems the users experience serve to identify parts of the interface that need to be fixed or completely redesigned. After several rounds of usability testing (each with 5 users typical of the target audience), we normally will resolve most problems and can then move on to developing computer prototypes. We do similar rounds of usability testing with the computer prototypes and authentic tasks. Then we move to final production of the software needed, and conduct production tests of the software with more users.

We will need user interfaces for the following functions: for students to input their ratings of instructional activities using the modified TALQ items for high school students; for teachers to select as well as input descriptions of instructional units, to link selected/constructed units to appropriate components in the curriculum map, and to enter individual student achievement scores for each instructional unit (i.e., based on tests, projects, grades); and for school administrative staff to enter curriculum maps and their component linkages.

We will need to have someone input the curriculum map for the high school, and if none exists one will need to be constructed. We will need to modify and test the TALQ items so that high school students can use them. This will require both usability testing of the interface for TALQ ratings by students and a reliability and validity study.

**Project Plan Year 2**

During the second year we plan to conduct a pilot test of MAPSAT Dashboard version 1 with a single high school, most likely the Applied Science and Technology Academy at Emmerich Manual High School in Indianapolis. We would begin in the fall and end in the spring of the school year. Based on what we learn from the ongoing evaluation we will attempt to make changes in the software and to develop necessary training materials for students, teachers and administrators on the use of the MAPSAT Dashboard system.

The state of Indiana will be requiring all students to pass tests in algebra, English and biology in order to graduate. The need in these three areas is well-documented (e.g., Achieve, 2008). Instead of working with all teachers initially, we will start with math teachers, since mathematical understanding and skills are needed in science, technology and engineering careers. Moreover, we plan to partner and collaborate with the Indiana STEM Resource Network to provide support to teachers. The MAPSAT Dashboard will indicate instructional units that receive low TALQ ratings from students, but teachers will need to find alternatives that can replace those units in the curriculum.

Participating teachers and school administrators would be trained to use the MAPSAT Dashboard software during the summer before the beginning of school in the fall. We would work with administrative staff and a curriculum specialist in the school district to input the goals for the curriculum map. A workshop would then be held with teachers to familiarize them with the curriculum goal map, how to enter descriptions of instructional units themselves, and how to make links from those units to goals in the curriculum map. Teachers would also be taught how to use the embedded grade book in the MAPSAT Dashboard for entering their assessments of student performance in instructional units. Finally, teachers would be shown how students will use the modified TALQ scales for rating student Academic Learning Time and First Principles of Instruction.

As the school year progresses, each participating teacher will enter a brief description of each new instructional unit when she or he begins it with her or his students. Units are expected to consist of 2-4 weeks of activities for a student project or chapters covered in a textbook. At the end of each instructional unit, the teacher will assess student learning and enter student scores into the MAPSAT grade book. After student scores are entered by the teacher, then each student will rate the instructional unit. This will take about 5 minutes using a computer connected to the Internet either at school or possibly at home.

MAPSAT project staff will monitor the database, backup data, and fix any software problems that arise during the year. About two months into the school year, a sample of students and teachers will be interviewed by project staff to see how things are going, and to identify problems or issues that need to be addressed. Interviews will also be done about 7 months into the school year.

At the end of the school year all participating teachers and students will be asked to complete surveys related to MAPSAT project evaluation (described in the evaluation plan).

**Project Plan Year 3**

This will be a small summative evaluation with four high schools in central and south central Indiana (one in Bloomington, one in Columbus, and two in Indianapolis). This will allow us to identify issues with scaling up. We anticipate following the same training and evaluation activities as we did in Year 2, but with three more schools. Again, we will initially focus on mathematics curriculum.

A longer term longitudinal evaluation of the MAPSAT Dashboard system is *not* possible in Year 3. We believe that it is realistically possible to develop, pilot test, and conduct a small field test of the Dashboard in the 3-year time frame proposed here. Following this, we plan to do a larger scale evaluation with random assignment of schools to the Dashboard or to a control group in order to determine the effectiveness of the Dashboard system in improving instruction and student learning achievement. This latter longitudinal evaluation will require additional funding and time beyond the three years we propose here. See Figure 3 below for a timeline of major project tasks and evaluation activities.

## Project Evaluation

One highly significant advantage of the MAPSAT Dashboard is that it: 1) collects and stores data on each school's curriculum goal map; 2) stores descriptions of instructional units undertaken by teachers during the school year; 3) stores teacher-made links between those instructional units and the goal map, teacher grades of student performance in each instructional unit; and 5) stores student TALQ ratings of each instructional unit on their perceived Academic Learning Time and their perceptions of First Principles of Instruction in each unit. Each of these data entries has a date/time stamp and user's ID. These data will be used as an important part of the project evaluation as well to answer the research questions on how much and when is MAPSAT used by teachers, students and administrators.

We will therefore be able to track changes in system structure according to these data. We will be effectively able to take "snapshots" of structure that are similar to the two graphs illustrated above in Figure 1. We can compute structural property measures each time the structure of the S-IU-C map changes. In fact, it is those measures that are displayed on the Dashboard that students, teachers and school administrators see (Figure 2 above). In sum, this kind of evaluation is built into the Dashboard and its underlying database. Along with those school personnel, we will be able to see property values change for strongness, flexibleness, interdependence, wholeness and vulnerability. As the school year progresses, then we should see a number of changes that can be measured from these data: 1) teacher links of units of instruction to curriculum goals, 2) teacher grades of student achievement of learning objectives in those units, and 3) student ratings of units of instruction on Academic Learning Time and First Principles of Instruction.

First, the evaluation should indicate an increase in system *size* and *complexity*. *Size* is the number of components. A curriculum goal is a component, a student is a component, and an instructional unit is a component. While goals and students would be expected to remain relatively stable during the year, we should see a *size* increase in the number of instructional units in the database. *Complexity* is the number of connections among components. *Complexity* should increase as teachers link instructional units to curriculum goals and as students are linked to instructional units by virtue of their participation in and mastery of learning objectives according to teacher grades.

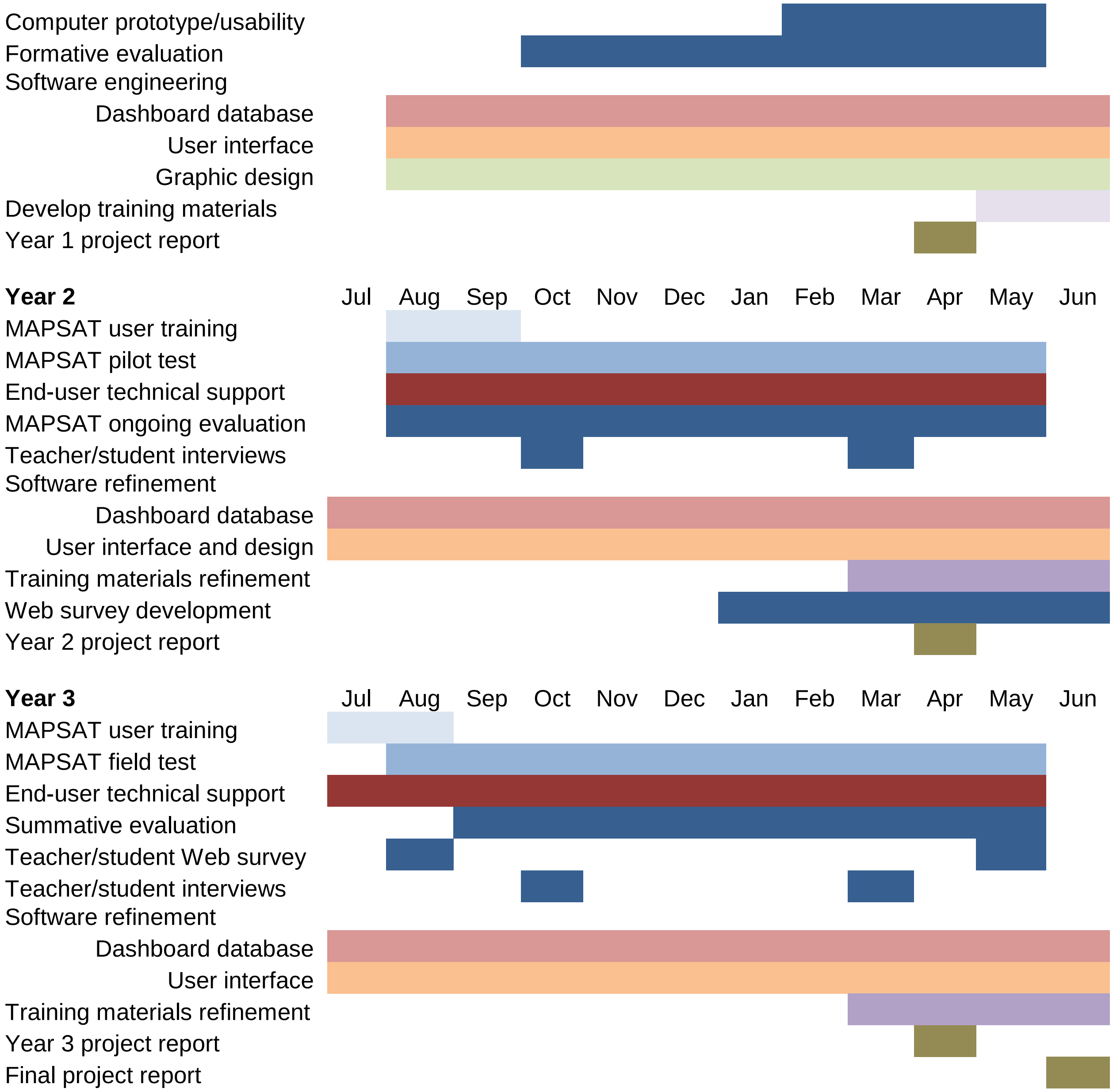
During the school year, the evaluation should show increases in *structural* property measures of strongness, flexibility, interdependence, and wholeness, and a decrease in vulnerability or it should remain low. If this is what happens, and if curriculum goals are associated with STEM careers, then this would be evidence that students are being better prepared for STEM careers during the school year. These structural measures are derived from ATIS Graph Theory (Thompson, 2008).

Finally, at the beginning and end of the school year we will administer Web-based surveys with items that ask students questions about specific knowledge and skills needed for STEM Careers and their attitudes towards those careers. As a consequence of using the MAPSAT Dashboard, students should be more aware of what [illegible] to pursue a career in STEM. Moreover, if students are successful in instruc[illegible]o STEM careers, their self-efficacy should improve with respect to their abili[illegible]e will develop and pilot test this survey during Year 2, and administer it at the beginning and end of Year 3. We plan to consult with STEM and self-efficacy measurement experts to identify existing instruments that we can adapt for our survey.

I worked closely with Dr. Frick to plan this development timeline.

**Figure 3: MAPSAT Curriculum Dashboard Timeline: Major Tasks for Years 1-3.**

| **Year 1** | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Needs assessment | | ▨ | ▨ | ▨ | | | | | | | | |
| Paper prototype/usability | | | | ▨ | ▨ | ▨ | | | | | | |



| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Computer prototype/usability | | | | | | | | ■ | ■ | ■ | ■ | |
| Formative evaluation | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | |
| Software engineering | | | | | | | | | | | | |
| Dashboard database | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| User interface | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Graphic design | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Develop training materials | | | | | | | | | | | ■ | ■ |
| Year 1 project report | | | | | | | | | | ■ | | |

| **Year 2** | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MAPSAT user training | | ■ | ■ | | | | | | | | | |
| MAPSAT pilot test | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | |
| End-user technical support | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | |
| MAPSAT ongoing evaluation | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | |
| Teacher/student interviews | | | | ■ | | | | | ■ | | | |
| Software refinement | | | | | | | | | | | | |
| Dashboard database | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| User interface and design | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Training materials refinement | | | | | | | | | ■ | ■ | ■ | ■ |
| Web survey development | | | | | | | ■ | ■ | ■ | ■ | ■ | ■ |
| Year 2 project report | | | | | | | | | | ■ | | |

| **Year 3** | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MAPSAT user training | ■ | ■ | | | | | | | | | | |
| MAPSAT field test | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | |
| End-user technical support | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | |
| Summative evaluation | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | |
| Teacher/student Web survey | | ■ | | | | | | | | | ■ | |
| Teacher/student interviews | | | | ■ | | | | | ■ | | | |
| Software refinement | | | | | | | | | | | | |
| Dashboard database | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| User interface | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Training materials refinement | | | | | | | | | ■ | ■ | ■ | ■ |
| Year 3 project report | | | | | | | | | | ■ | | |
| Final project report | | | | | | | | | | | | ■ |

In summary, it can be seen in Figure 3 that in Year 1 evaluation activities will be formative during design and development, with usability evaluations of paper and computer prototypes. Year 2 will consist of a pilot-test of the Dashboard, with ongoing data collection throughout the school year. Teachers and students will be interviewed in the middle of the fall and spring to get first-hand reports on how the Dashboard is being used. These interview data will supplement logs automatically kept in the MAPSAT Dashboard database that will indicate who, how often, and when the Dashboard is being used and for what activities. We will also be able to compute changes in MAPSAT Dashboard structural property values throughout the school year, as described above. During Year 3, the same kinds of evaluation activities will occur, as in Year 2, but with a total of 4 high schools. During Year 3, we will be able to do pre- and post-testing of students and teachers with the Web survey developed in Year 2. This survey will allow us to observe whether students and teachers are more knowledgeable about connections between instructional units and STEM careers, and whether student self-efficacy and interest in STEM careers has increased. The instructional unit descriptions in this survey will *not* be ones that teachers and students have seen before (i.e., not used by them during the school year).

### Qualifications of Key Personnel

*Principal Investigator and Project Director: Theodore Frick*. Dr. Frick most recently served as long-time Web Director for the Indiana University (IU) School of Education, where he designed, developed, evaluated and managed a complex, highly successful Website for the School of Education, supervising a staff of 28 content providers. He also provided leadership for the IU Bloomington campus in development of its Website. He has extensive experience in successful design and development of software for educators, most recently with online, interactive Web technologies (e.g., the *Diffusion Simulation Game* and *How to Recognize Plagiarism*). He has done seminal work on inventing algorithms for computerized classification tests (Frick, 1992). He is the creator of MAPSAT Analysis of Patterns in Time (APT: Frick, 1990), and has written computer algorithms for Analysis of Patterns in Configurations (APC: Thompson, 2008). He has been principal or co-principal investigator on numerous technology-related projects since 1976 with total funding of over $3M.

*Co-Principal Investigator and School Liaison and Coordinator: Catherine Brown.* Dr. Brown has served as Associate Dean for Research and Development in the IU School of Education, a position from which she is stepping down in June, 2008, to return to full-time research and teaching. Dr. Brown is a well-known and respected mathematics educator, and has been working with the Indiana schools in order to improve learning in mathematics.

*Software Development.* Rodney Myers, Ph.D. student at IU, has over 20 years of experience as a software engineer. He most recently worked at Santa Clara University in developing and implementing Web applications, database applications and information management systems to facilitate administrative decision making.

*Project Evaluation: Jaesoon An*. Dr. An is a research associate in the Pervasive Technologies Labs at Indiana University. She is an evaluation specialist, particularly in usability testing and evaluation of computer software products. She previously worked in this capacity at Microsoft and subsequently at Samsung Corporation. The Pervasive Technologies Labs are *independent* from and not part of the School of Education at Indiana University Bloomington. The mission of the Pervasive Technologies Labs is to: “perform leading-edge research based on the pervasiveness of information technology in our world, creating new inventions, devices, and software that extend the capabilities of information technology in advanced research and everyday lives” (Pervasive Technology Labs, 2008). Dr. An routinely evaluates new products and software created at the Labs, and will conduct evaluations of our MAPSAT Curriculum Dashboard Project.

*Project Partners: Indiana Public High Schools.* The Indiana University School of Education has established an agreement to work with IPS called the Pathways Initiative. We plan to partner specifically with the Applied Science and Technology Academy at Emmerich Manual High School in Indianapolis during the first two years. During the third year, we plan to partner with Arsenal Tech High School, also part of the Pathways Initiative, as well as New Tech high schools in Bloomington and Columbus, Indiana.

*Project Partner: I-STEM.* “The I-STEM Resource Network is a partnership of Indiana’s public and private higher education institutions, K-12 schools, business, and government. It supports K–12 teachers and leaders working to implement high academic standards towards STEM literacy for all students. It also provides Indiana education leaders with new knowledge about teaching and learning” (I-STEM Resource Network, 2008, n.p.).

### Anticipated Impact of the MAPSAT Curriculum Dashboard Project

The expected outcomes of the MAPSAT Dashboard Project are to: 1) improve the *relevance* of high school curriculum for STEM careers; 2) improve *student awareness* of knowledge and skills needed for STEM careers; 3) improve the *quality of instructional units* in high school curricula so that they are *more meaningful* to students and result in higher levels of successful student engagement; 4) improve the *structure* (i.e., connectedness) of instructional units and curriculum maps in high school with respect to their relatedness to STEM careers.

While the short-term impact of the MAPSAT Dashboard on 4 high schools is important, the potential for long-term impact is to *facilitate the transformation of the curriculum in P-12 schools across the U.S.* One of the significant barriers to major school improvement is the structure and content of curriculum itself. Grade levels and textbooks around which the current curriculum is structured have largely been designed with respect to separate subjects—e.g., reading, writing, arithmetic, social studies, health, algebra, biology, etc. While the importance of these areas of learning is not being questioned here, when these subjects are taught and learned in "silos," the connectivity to real-world problems and career needs in today's world has gotten lost. It has recently been documented that most high school students are bored in class every day and do not see the relevance of what they are supposed to learn. When schools start using the MAPSAT Dashboard with existing instructional units in the curriculum, the poor connectivity between those units and STEM careers should be obvious. As teachers improve instructional units so that they are viewed as being connected to real life and subsequent careers, students will see the relevance. This will help motivate those students to make a greater effort to learn. If they make more effort, they are more likely to be more successful in their learning. If these instructional units are connected also to STEM careers, then students will be better prepared for those careers when they graduate.

In this proposal, we need to first create the software and user interfaces for the MAPSAT Dashboard. To do this right, we will be following a well-established design, development and evaluation strategy. This is an iterative strategy that results in successive improvements while actually testing prototypes with the target users, who are high school students, teachers and administrators. These users participate in the development and help shape the final version of the product so that it will be easy for them to use and meet their needs. It would be ill-advised to rush to disseminate the MAPSAT Dashboard widely until the evaluation indicates that it is working well with the intended users. We believe that a 3-year timeline is feasible and realistic with resources for which we have budgeted.

## Follow-Up Evaluation Study Needed before Widespread Implementation

As we approach the end of this proposed project, then we will know enough to anticipate requirements for a rigorous, longitudinal, multi-year evaluation. At that time, we would seek funding for a larger-scale evaluation. During Years 4-6, in such a study, we would be able to randomly assign schools to the MAPSAT Dashboard or to a control group that does business as usual. Then, by evaluating these two groups longitudinally, we would be able to measure change in curriculum and resulting student achievement in curriculum areas associated with STEM careers.

Assuming that evaluation outcomes demonstrate the effectiveness of the MAPSAT Dashboard, it could be implemented widely. Because we are using a server-client delivery system over the Internet with non-proprietary software and hardware, the MAPSAT Dashboard could be implemented either at a school district level or at a national level. If a school district were to adopt the MAPSAT Dashboard, then that school district would be responsible for buying the Linux server(s) and securely maintaining the MAPSAT Dashboard database for their district. If MAPSAT were implemented at a national level, then it would operate similar to Google. The hardware, servers and MAPSAT databases could be maintained by Indiana University or some other non-profit organization that has sufficient network bandwidth and technical support. School districts would be charged nominal licensing fees to cover costs of operation. The advantage of such a centralized resource would be that teachers everywhere could have access to and share instructional units that are connected to curriculum goals that help prepare students for STEM careers.

## Afterword: Transformative Ideas and Risk

The methods of measurement that are part of the proposed MAPSAT Dashboard are unconventional and have not been widely used, although several extant studies were cited earlier that demonstrate the value of these methods (cf. Frick, 1990; Koh & Frick, 2007; Frick *et al.*, 2007 in press; 2008). These methods represent a paradigm shift in approach to measurement of educational phenomena (cf. Kuhn, 1996). Experts in traditional forms of educational measurement are likely to express doubt about MAPSAT methods, because they are new, “unproven” and different. Traditional measurement normally assesses parts of the world separately. Then those measures, represented as values of variables, are analyzed statistically using one form of algebraic linear model or another (e.g., regression, MANOVA). MAPSAT, however, is predicated on a systems view of the world in which the *relations* are measured, not just the separate parts. The analysis in MAPSAT is logical in the sense that a pattern is first identified and then occurrences of that pattern are counted.

Thus, from the traditional paradigm of quantitative measurement in education, MAPSAT is likely to be viewed as being unknown or untested. Yet NSF has recently added a new criterion regarding the transformative value of new ideas. As Kuhn argued, those researchers in the earlier paradigm are essentially blind to a new one that, if it takes hold, will eventually supplant it. Thus, those new ideas appear to be risky, if not threatening, to the established way that things are done. If funded, this proposed Dashboard project will be a way to test the practical value of MAPSAT methods.

Those who understand Bayesian Network Analysis and Social Network Analysis (e.g., Brandes & Erlebach, 2005) should recognize that MAPSAT is grounded in graph theory, as is BNA and SNA. Researchers who are doing BNA and SNA may wonder why we have not adopted either of these approaches. More generally, Brandes and Erlebach (2005) would identify these as different types of *network analysis*. While it is true that MAPSAT, BNA and SNA are fundamentally based on graph theory, they do not end up in the same place. What has shaped MAPSAT is general systems theory (cf. Maccia & Maccia, 1966) and in particular Axiomatic Theories of Intentional Systems (Thompson, 2005a, 2005b, 2008). Thus, MAPSAT temporal and structural properties will include ideas that are not part of BNA or SNA. For example, ‘adaptableness’ and ‘compatibleness’ are dynamic properties of systems, and ‘wholeness,’ ‘complexness’ and ‘heterarchiness’ are structural properties (there are over 100 system properties in ATIS). Analysis of Patterns in Time (MAPSAT APT) is needed to measure ‘adaptableness and compatibleness.’ Analysis of Patterns in Configuration (MAPSAT APC) is needed to measure ‘wholeness,’ ‘complexness’ and ‘heterarchiness.’

However, we do not intend to include all ATIS properties in the MAPSAT Curriculum Dashboard. We do intend to include those which are expected to be useful for considering change in curriculum structure within a school system; and that is why we have limited Dashboard measures to strongness, flexibility, interdependence, wholeness and vulnerability. A broader and longer term perspective on this theoretical development is explicated in Frick and Thompson (2007, in press). The aim of the present proposal is to apply MAPSAT to help schools modify their curriculum structures to be better connected to STEM careers. This Dashboard is feasible to build and evaluate in a relatively short period of time (3 years), so that educators can then begin to measure changes they make in their curriculum structures.

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