SimTIE-Math Project Summary

The *SimTIE-Math* Project addresses NSF 08-609 DR-K12 challenge A3, “How can the ability of teachers to provide STEM education be enhanced?” (RFP p. 5) through the proposal type, “Research and development projects” (RFP p. 7). We propose to design, develop and evaluate a simulation-game, *SimTIE-Math,* for preservice teachers to improve their ability to select elementary-level mathematics learning activities that maximize student task success and learning achievement in mathematics.

Intellectual merit. Three research questions will be addressed: When compared with preservice teachers who do not play *SimTIE-Math*, are preservice teachers who extensively play *SimTIE-Math* better able to: 1) predict the success of mathematics learning activities for individual elementary school children? 2) accurately identify each student’s individual mathematics learning trajectory, given evidence of their performance on mathematics tasks? and 3) integrate appropriate information technologies in elementary-level mathematics learning tasks so as to provide more individualized instruction?

SimTIE-Math is a simulation-game on technology integration in education (TIE) in teaching elementary-level mathematics. It is primarily intended for preservice teachers, although any adult could play it, including teachers in the field. We have already designed, developed and play-tested a paper prototype of *SimTIE* with preservice teachers. This is currently a board game that we propose to expand and transform into a digital version that will run over the Web. In the current vision of *SimTIE-Math*, when the simulation-game begins, a player randomly gets specific simulated students in his/her simulated classroom. He or she will need to access information about those students via their individual profiles. While playing *SimTIE-Math*, a preservice teacher will be challenged repeatedly to make decisions necessary to integrate technology into student learning activities, so that they more effectively individualize instruction to move simulated students towards achievement of state curriculum standards in elementary-level mathematics. During successive rounds of play in *SimTIE*, a preservice teacher will need to sequence learning activities that are in step with where each simulated student is in his/her *learning trajectory* and within his/her zone of proximal development. Additionally, assessment logs are updated to reflect each student’s mastery of curriculum standards (i.e., in numbers and geometry) that are updated according to success or failure of learning activities selected during each round of play. If *SimTIE-Math* players choose appropriate learning activities, they will see changing graphs on each simulated student that indicate specific progress towards those standards. A player wins by getting all of his or her simulated students to achieve state mathematics standards in a simulated “school year.” Levels of difficulty in *SimTIE-Math* will increase as the number of students in the simulated classroom increases and the resources available to manage increase. We expect to design *SimTIE* such that, in future versions of this simulation-game, additional learning activities in *different* subject areas can be inserted, so that others can more easily create *SimTIE-Biology*, *SimTIE-Algebra*, *SimTIE-Physics, SimTIE-Electronics,* etc.

Four-year plan. During Years 1 and 2 we expect to iteratively design, develop and formatively assess computer prototypes following a design framework for complex learning (cf. van Merriënboer & Kirschner, 2007), understanding by design (Wiggins & McTighe, 2001) and a curriculum research framework (Clements, 2007). This approach is expected to lead to a production version of *SimTIE-Math* to be subsequently evaluated during Year 3 in teacher education mathematics methods courses at Indiana University. During Year 4, summative evaluation of *SimTIE-Math* will continue, as preservice teachers do their student teaching in K-6 classrooms, in order to address the primary research questions stated above.

Multi-disciplinary research team. We have assembled a talented, multi-disciplinary group of faculty and graduate students to build *SimTIE-Math*. We have faculty expertise in Mathematics Education; in design and programming of serious simulations and games from Instructional Systems Technology; in interaction design and user engagement from Informatics; and from the Indiana University Center for Evaluation and Education Policy (CEEP) to evaluate this project.

Broader impacts. Over time, *SimTIE-Math* is expected to improve teacher selection of mathematics learning activities for elementary-level school children that, in the long run, leads to: 1) improved student learning achievement in mathematics; 2) appropriate integration of information technologies to better customize student learning; and 3) teachers who are better prepared for the transformation of schools that is likely to occur in the next decade (cf. Christensen, Johnson & Horn, 2008).

SimTIE-Math Project Description:
A Simulation-Game on Technology Integration for Mathematics Learning

1. Goals and Purpose: Overview

We propose to design, develop and evaluate a simulation-game, *SimTIE-Math,* for preservice teachers to improve their ability to select learning activities in elementary-level mathematics that maximize student task success and learning achievement. We plan to complete this project over 4 years.

During the first 2 years, we plan to iteratively design, develop, play-test and evaluate rapid prototypes of *SimTIE-Math.* Each prototype will be formatively evaluated during successive rounds of play-tests with small numbers of preservice teachers at the Indiana University *User Engagement Lab* in the School of Informatics. An external evaluator will monitor this iterative development process.

During years 3 and 4, summative evaluation of *SimTIE-Math* with preservice teachers is planned—also to be done by an external evaluator through a staggered longitudinal comparison, as these teachers move through the last 2 years of their teacher education program. Preservice teachers who play *SimTIE-Math* during Year 3 will be evaluated during mathematics methods classes and educational technology courses in the School of Education, while *at the same time* preservice teachers who have not played *SimTIE-Math* are evaluated during their student teaching (which occurs during the last year of their teacher education program). Further evaluation will be conducted when those Year 3 preservice teachers move on in Year 4 to do their student teaching. Three primary research questions will be addressed: When compared with preservice teachers who have not played *SimTIE-Math*, are preservice teachers who have extensively played *SimTIE-Math* better able to: 1) predict the success of mathematics learning activities for individual elementary school children? 2) accurately identify each student's individual mathematics learning trajectory, given evidence of their performance on mathematics tasks? and 3) integrate appropriate information technologies in elementary-level mathematics learning tasks so as to provide more individualized instruction?

The proposed project is a multi-disciplinary effort led by faculty in Instructional Systems Technology and Mathematics Education in the School of Education, combined with faculty expertise in the School of Informatics at Indiana University and with support from the Center for Research on Learning and Technology (*CRLT*). External evaluation of this project will be conducted by professional staff at the IU Center for Evaluation and Educational Policy (*CEEP*). Beyond the 4-year *SimTIE-Math* project proposed here, a multi-year, longitudinal follow-up study is also planned for further field testing at other U.S. institutions who prepare teachers.

1.1 Rationale: Issues in Preparation of Teachers of Mathematics

Traditional and alternative approaches to the preparation of teachers have received increasing attention in the press and in research studies in recent years (Cochran-Smith, & Zeichner, 2005; ECS, 2003a; ECS, 2003b; Kane, Rockoff, & Staiger, 2006; National Mathematics Advisory Panel, 2008). Our proposed development and research will contribute to the empirical evidence about the practices required to prepare highly qualified elementary mathematics teachers. We will study the potential of an innovative practice for preparing teachers who are better at paying attention to students' individual differences, and who are knowledgeable in selecting differentiated learning activities.

Researchers have found that effective teaching requires knowing how specific individual students in the classroom think about the content (Carpenter & Fennema, 1992; Carpenter et al., 1988; Carpenter, Fennema, & Franke, 1996; Cobb, 2000; Fennema et al, 1996). Furthermore, there is evidence to show that teachers can improve their content knowledge as they work to understand students' reasoning (Franke & Kazemi, 2001). In the proposed project, preservice teachers will work with simulated students and will have to choose learning activities that are appropriate for where their students are in relation to mathematics standards. They will then see the effect of their choices on their simulated students' learning and will refine their understanding of their students' knowledge. By providing opportunities for preservice teachers to go through cycles of refining their ability to make instructional choices based on their assessment of students, we are likely to find some of the benefits reported by professional development studies, including: increased efforts to improve student learning (Bloom, 1998), critical reflection on teaching practices (Lord, 1994), and strengthened content knowledge (Nickerson & Moriarty, 2005).

1.2 Rationale: Research on Pedagogical Content Knowledge of Mathematics

Research and recent documents highlight the importance of effective mathematics teachers having well-developed understandings in domains of content and pedagogy (Ball, 1991; Conference Board of the Mathematical Sciences [CBMS], 2000; Duschl, Schweingruber, & Shouse, 2006; Ma, 1999; Mathematical Association of America, 2003; National Mathematics Advisory Panel, 2008; Smith, Desimone, & Ueno, 2005). Recognizing that the intersection of these domains is most critical, researchers have focused on teachers' development of pedagogical content knowledge (Ball, Lubienski, & Mewborn, 2001; Borko & Putnam, 1995; Grossman, 1990; Grouws & Schultz, 1996; Schwartz & Lederman, 2002; Shulman, 1986). Pedagogical content knowledge provides the basis for teachers' decision-making within a discipline; it includes seeing the topics they teach as embedded in rich networks of interrelated concepts, deciding on the use of tasks, selecting useful representations of the ideas involved, teaching mathematics and science as an integrated body of knowledge and practice, and understanding what makes the learning of specific topics easy or difficult for students (CBMS, 2000; Duschl, Schweingruber, & Shouse, 2006; Shulman, 1986; Van Driel, Verloop, & deVos, 1998).

One way for teachers to develop their pedagogical content knowledge is by attending to students' reasoning. The premise is that if teachers listen to children, understand their reasoning, and teach in ways that reflect this understanding, not only will they provide those children with a better mathematics and science education, but this will also have a powerful effect on the way teachers view mathematics learning (Appleton, 2006; Carpenter & Fennema, 1992; Fennema et al., 1996; Franke, Carpenter, Levi, & Fennema, 2001; Morine-Dershimer & Kent, 1999; Schifter, 1998; Warfield, 2001). The proposed simulations will help preservice teachers learn to attend to students' reasoning by choosing learning tasks that they think are appropriate for students' knowledge of mathematics concepts and by seeing the effects using those tasks on students' learning.

1.3 Rationale: Building Learning Trajectories

Contemporary research on children's mathematical learning highlights the efficacy of building models of students' knowledge (Carpenter, Fennema, Peterson, & Carey, 1988; Confrey, 1985, 1990; Confrey & Lachance, 2000; Steffe, 2002; Steffe, Cobb, & von Glasersfeld, 1988; Steffe & D'Ambrosio, 1995). Math Recovery, which relies on model building for its highly successful interventions with at-risk students, describes model building as "on-going assessment through careful observation, hypothesizing about the student's current knowledge and strategies, and selecting learning activities closely attuned to the child's current reasoning and strategies" (US Math Recovery Council, 2005, p. 6). Steffe and D'Ambrosio (1995) have suggested that model building should be the central component to teachers' pedagogical knowledge. Our proposed approach follows such research and suggestions by engaging preservice teachers in building learning trajectories of their simulated students and choosing learning activities according to the models they build of their students' knowledge.

Teaching experiments involve a close examination of teacher-student and student-student interactions that support learning. Teaching experiment methodology requires a particular approach to teaching in which the teacher must continually attempt to make sense of the students' language and actions (Steffe & Thompson, 2000). This approach is important on two levels. First, by continually interpreting student behavior, the teacher is developing new hypotheses about students' cognition while remaining open to surprises. Second, by attempting to think as students do, the teacher is in a position to understand the students' ways of operating and compare them to his own in order to design tasks to provoke creative activity in the students (Hackenberg, 2005). On both levels, the teacher experiences constraints in building viable models and meaningful tasks based on the dichotomy of expected (predicted) and observed activities of students. This feedback provides the guiding principle for hypothesis testing, model building, and the design of new tasks within and between protocols.

Although teaching experiments have been used successfully in research on learning and as interventions for at-risk children, they have not been used as part of an undergraduate program for preservice teachers. We propose designing simulations that will allow preservice teachers to learn to develop the skills needed to conduct teaching experiments in order to learn to build models of children's mathematical knowledge and in order to learn to follow the development of children's ideas over time.

1.4 Rationale: More Academic Learning Time (ALT) Is Needed in Preservice Teacher Education

One of the challenges that teacher preparation programs face is providing preservice teachers with enough relevant teaching experience. Typically preservice teachers may spend several weeks early in their teacher education program visiting K-12 schools and observing teachers and students (i.e., early field experiences). They may have occasional opportunities to visit again while they take courses on teaching methods. Preservice teachers typically end their preparation with a semester of teaching in a K-12 school in their area of licensing, while under supervision of a practicing licensed classroom teacher (i.e., student teaching experience). In effect, these college graduates enter the teaching force with relatively little actual experience teaching real K-12 students, and have no choice but to mostly learn on the job. Imagine if commercial airline pilots or medical physicians were prepared this way.

Yet we know both from learning theory and research on academic learning time (ALT) that frequency of successful practice is a strong predictor of academic achievement (cf. Berliner, 1990; Brown & Saks, 1986; Kuh, Kinzie, Buckley, Bridges, & Hayek, 2007; Rangel & Berliner, 2007). However, when we prepare college students to become teachers, the amount of time they successfully practice teaching in their licensing area (with appropriate coaching and feedback) is restricted to a few months of practice teaching (as student teachers). The practicality of gaining more successful practice teaching in real classrooms is logistically difficult and resource-intensive (e.g., time and expense for preservice teacher travel to schools, finding enough placements in classrooms, potential disruption of ongoing education in K-12 classes, time demands on licensed classroom teachers for supervision, etc.).

Moreover, learning to teach is a form of complex learning. We know from extant research that complex learning by adults is best facilitated by engaging in a series of real-world (authentic) tasks that are arranged in groups of increasing complexity—van Merriënboer and Kirschner's 4C/ID model (2007), Merrill's First Principles of Instruction (2002)—accompanied by appropriate scaffolding, supportive information, just-in-time information and part-task practice. We also know from research on the development of expertise that it takes about 10 years of such engagement to become outstanding in a profession (cf. Ericsson, Krampe, & Tesch-Römer, 1993). Thus, the problem faced by teacher education programs is how to increase successful practice in teaching, given the constraints that most colleges and universities face.

Simulation is one way that successful practice with feedback can be increased. For example, the benefits of flight simulators for training and maintenance of flying skills are well-known and documented. It is routine now for both military and commercial airline pilots to spend numerous hours in flight simulators, before actually flying the real plane. The reasons are clear. Beyond increasing academic learning time (successful practice), the advantage of such simulators is to practice also under conditions that are rarely encountered in the real world. Most importantly, pilot errors that are made in the simulator do not result in human fatalities and loss of expensive airplanes. Pilots can learn from these mistakes, and improve their flying skills. A meta-analysis of flight simulation research (Hays, Jacobs, Prince, & Salas, 1992) found that aircraft training combined with the use of simulators consistently resulted in improved performance compared to aircraft training only.

1.5 Rationale: Why Serious Simulations and Games are Important—What the Research Indicates

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; Magnussen, 2005; Ruben, 1999); and the relationship between game design and instructional design (Becker, 2005, 2008; Dickey, 2005; Van Eck, 2007).

Research on the use of simulations and games for learning seems to be increasing. Rutter and Bryce (2006) compared the periods of 1995-1999 and 2000-2004 and found nearly twice as many peer-reviewed papers on digital games during the latter period. Bragge and Storgards (2007) used the ISI Web of Science to find 2,100 studies in more than 170 categories related to digital games between 1986 and 2006, with a significant increase beginning in 2003. However, much of the reporting on the use of games for learning is anecdotal, descriptive, or judgmental and not tied to theory or rigorous research (Gredler, 2004; Kirriemuir & McFarlane, 2004; Leemkuil, de Jong & Ootes, 2000; Washbush & Gosen, 2001; Wideman et al., 2007).

Regarding the use of games and simulations with preservice teachers, Kay (2006) reviewed 68 refereed journal articles that focused on incorporating technology into preservice education. He identified ten common strategies, including the use of multimedia (case studies, online courses, and electronic portfolios). He did not report any use of simulations with preservice teachers. Schrader, Zheng, and Young (2006) surveyed 203 preservice teaching students in three different universities regarding their attitudes toward the use of games in education. The majority (76.4%) had played games, and of those, 83.3% played on a weekly basis. Participants recognized the distinction between recreational games and educational games, identifying problem-solving (78.8%), clear rules (63.5%), authenticity (52.2%), and feedback (43.8%) as important characteristics of educational games. The researchers noted that "the data does indicate that preservice teachers are open to new applications of technology and in fact consider games to be important educational tools" (p. 4).

Why Use Simulations/Games to Teach? Two main reasons for using instructional simulations/games are their power to engage and motivate and their ability to facilitate learning through doing (Kirriemuir & McFarlane, 2004). According to Garris et al. (2002), there are several reasons why educators should be interested in using simulations and games in instruction, including the shift to a learner-centered model and the intensity of involvement and engagement in games. The memorization of facts and concepts that are easily measured on a standardized test has led to the presentation of abstract, decontextualized knowledge that is divorced from purpose and instrumentality. In contrast, simulations require players constantly to use what they have learned to solve situated problems (Shaffer, Squire, Halverson & Gee, 2005; Wideman et al., 2007). Findings demonstrate that the kinds of experiential learning available in simulations and games improve learners' problem-solving skills and judgment. In part this is because the active learning required in games facilitates integration of knowledge with existing cognitive structures (Feinstein & Cannon, 2002; Randel, Morris, Wetzel, & Whitehill, 1992).

In their review of the literature, Mitchell and Savill-Smith (2004) found several frequently cited benefits of games in education. These include increases in perseverance, confidence, and self-esteem among learners; the ability to visualize, manipulate, and explore concepts; and greater academic, social, and computer literacy skills. Some studies cited improved metacognition, strategic thinking, problem recognition, and problem solving. In the health sciences, simulations enable students to diagnose and manage virtual patients' problems. In business education, teams manage virtual companies. In both areas, simulations are used to identify students' problem solving abilities and to bridge the gap between classroom instruction and real-world practice (Gredler, 2004).

Many of the attributes of games are also attributes of good instructional design. Games often involve problem solving, provide rapid feedback, and can adjust to optimal level of difficulty (Oblinger, 2006). Gee (2003; 2005) identified dozens of learning principles that are found in good games, including manipulation and control by the learner, scaffolding and elaboration, well-ordered problems, optimal challenge, skills as strategies and cycles of expertise, information as needed (just in time), systems thinking, and learning by doing.

Many studies of the benefits of playing games to learn have emphasized the motivational or social aspects rather than knowledge acquisition (Kafai, 2001). However, intrinsic motivation is generally considered a prerequisite for learning. Garris et al. (2002) describe the motivated learner as enthusiastic, engaged, focused, and persistent. The factors that make an activity intrinsically motivating are challenge, curiosity, and fantasy (Malone, 1981). Not surprisingly, these are all common elements of games. Garris et al. (2002) propose an input-process-output game model that facilitates intrinsic motivation. The input is a combination of instructional content and game features. The features promote a game cycle of user judgments, user behavior, and system feedback in an iterative loop which, when successful, results in increased engagement, greater persistence of effort, and greater likelihood of achieving intended learning outcomes.

How Games Are Used for Instruction. Gredler (2004) states that the purposes of games and simulations in education are to practice or refine existing knowledge and skills, to identify gaps or weaknesses in knowledge or skills, to develop new relationships among known concepts and principles, and to serve as a summation or review. These are consistent with reviews of the reported use of games, in which games were most frequently used to learn new skills and practice existing skills, generally after the learners had received some introductory instruction to prepare them for the game (Dempsey et al., 1993-1994; Dempsey et al., 1996). Options for integrating games into a curriculum include use as a pre-instructional strategy, a co-instructional strategy, and a post-instructional strategy (for assessment and synthesis) (Oblinger, 2006).

A review of the literature led Leemkuil et al. (2000) to conclude that there is some consensus that games and simulations will not be effective unless accompanied by instructional support, such as model progression, prompting, feedback (from the game/simulation or the instructor or peers), debriefing, and reflection. Gredler (2004) concurs that open-ended, discovery learning in a simulation is problematic. She recommends that students acquire required knowledge and capabilities (including metacognitive skills) prior to using a simulation. Research consistently concludes that students need some structure in order to learn in discovery-oriented simulations (Kirschner, Sweller, & Clark, 2006). Rieber (2005) recommends short explanations offered at the appropriate times within the simulation. He also suggests model progression in which the simulation becomes increasingly difficult based on the learner's mastery of required skills.

Summary. It is clear that well-designed serious simulations and games are not a passing fad, but have the potential to become a staple of future education. Until the invention of the printing press some 500 years ago, students relied mostly on teacher lectures as their primary sources of information. In the 19th and 20th centuries, textbooks have been a staple of education. In the 21st century, the new "textbooks" will be interactive digital learning experiences (cf. Christensen, Johnson, & Horn, 2008). Serious simulations and games are likely to become one of the important ways that students will be learning.

1.6 Rationale: Paucity of Simulations in Teacher Education

Simulations of teaching are rare. We have identified a small number of simulations for preservice teachers that are currently in use or under development, including *Aha! Classroom Sim* (Oskorus, 2007; Payne, 2006), *Cook School District Simulations* (Girod & Girod, 2006; Girod, Girod, & Denton, 2007), *SimSchool* (Gibson, 2007; SimSchool, n.d.), *SimClass* (Baek & Kim, 2007), and *Teaching Literacy in a Virtual Kindergarten Classroom* (Ferry & Kervin, 2007). In general these simulations differ from *SimTIE-Math* in their models and underlying theories, their focus and goals, and their interfaces. None of these focuses either on technology integration or the teaching of mathematics.

2. R&D Design: Overview of *SimTIE-Math*

We believe that *SimTIE-Math* can increase successful teacher engagement in activities that will better prepare them to teach mathematics. *SimTIE-Math* will give preservice teachers practice in selecting appropriate learning activities in mathematics so that they can experience the consequences of their classroom teaching decisions. Each preservice teacher manages a simulated classroom in which she or he must facilitate individual student engagement and learning achievement by identifying activities and resources most appropriate for their simulated students. A teacher succeeds in *SimTIE-Math* by most efficiently guiding her or his simulated students' mastery of curriculum standards in mathematics during a fixed period of time.

The advantage of such a simulation for teachers is similar to that of cockpit simulators for pilot training: users will get repeated practice and feedback in managing a simulated classroom under various conditions so that their simulated students successfully learn mathematics—or not—and likewise learn from their mistakes without harming students or losing their jobs.

Background of SimTIE. In the spring of 2007, the Principal Investigator led an advanced production class on design of serious simulations and games. This class was very successful in designing a paper prototype for a new simulation-game we invented together, called *SimTIE: Simulating Technology Integration in Education*. This is intended for preservice teachers as well as for practicing teachers in the field, to help them make good choices when attempting to use information technology to enhance learning and teaching. This *SimTIE* board game was improved over several iterations of rapid prototyping and play-testing (usability evaluation). Teacher education students and faculty who played the board version were excited about the potential for use in teacher education programs.

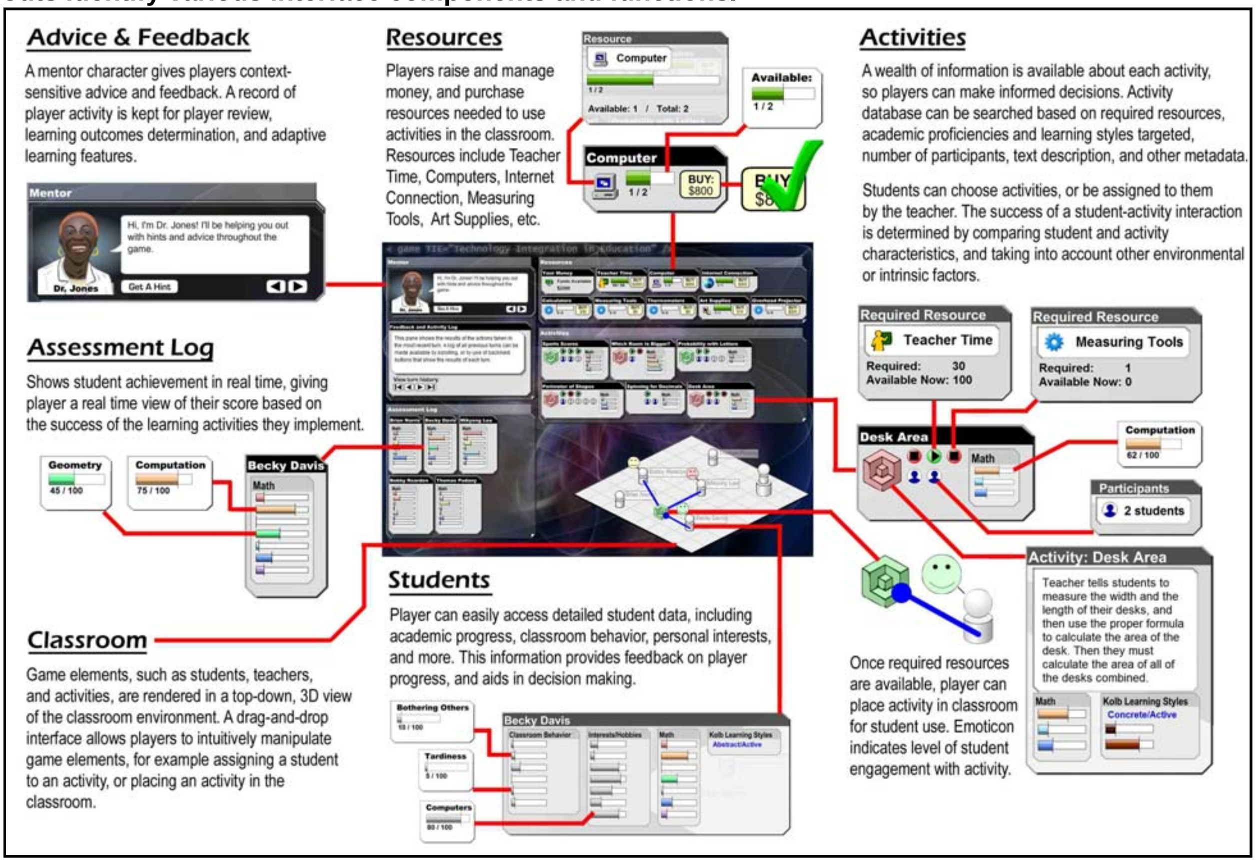
2.1 R&D Design: How *SimTIE-Math* is Expected to Work

We view *SimTIE-Math* as a learning resource on the Web that can be played by preservice teachers repeatedly—anytime, anywhere throughout their teacher education program. The value of such a learning resource is the Academic Learning Time (ALT) that preservice teachers accumulate as they are repeatedly engaged in thinking about how to customize elementary students learning of math. We expect these teachers to be initially exposed to *SimTIE-Math* when they take educational technology classes. We further expect *SimTIE-Math* to be a learning resource for preservice teachers when they take their mathematics education methods courses and to serve as a vehicle for class discussion in these courses. Moreover, these preservice teachers could subsequently use *SimTIE-Math* when doing their student teaching in K-6 classrooms for actual planning of student learning activities. Altogether preservice teachers could spend many hours playing *SimTIE-Math*, as they are challenged by increasing levels of difficulty each time they master a level, similar to what happens when people play video games for entertainment.

As can be seen in Figure 1, a possible interface for *SimTIE-Math* is illustrated. This is a computer graphic, not an actual working interface. It nonetheless illustrates a starting point for us to build upon. An effective way to design software for simulations and games is what is called the Model-Viewer-Controller (MVC) architecture, which is how the simulation-game design itself is implemented on computers. The design of the game content itself and rule system for the game is also described briefly:

Viewer components in the user interface. Figure 1 illustrates components of the user interface with which the person who plays *SimTIE-Math* interacts and which provides the feedback to decisions and moves he or she makes during the simulation-game. As can be seen, this a 2-D interface, in order to reduce the cognitive load on users (cf. van Merriënboer, Kirschner, & Kester, 2003), so that they can focus on selecting appropriate activities for their simulated students. It is not one with an avatar wandering through 3-D space interacting with other avatars (e.g., as in Second Life), which would be much more costly and which might distract users from the main purpose. What is most important is the teacher decision making necessary to integrate technology into student learning activities such that they effectively move those students towards achievement of state curriculum standards (e.g., for elementary school learning of mathematics, K-6). As can be seen in Figure 1, a player will need to select learning activities that are appropriate to the specific learning trajectory of each simulated student in *SimTIE-Math.* Through chance (a computer "roll of the die"), the player ends up with specific simulated students and will need to access information about them via their profiles (but nothing explicit about where each is in his/her learning trajectory, although this "hidden" information is used by *SimTIE* in modeling each student). Additionally, the assessment logs will indicate for each simulated student his or her level of mastery of curriculum standards in numbers and in geometry. If *SimTIE-Math* players choose appropriate learning activities, they will see changing graphs on each simulated student that indicate specific progress towards those standards.

Figure 1. What the computer version of the *SimTIE-Math* user interface might look like. The call-outs identify various interface components and functions.



Controller components—implementing the rule system. The *Controller* part of the MVC architecture is the software which takes the learning activities that a player selects during his or her "move" in the simulation and then generates an appropriate outcome, given the "rule system." These rules are expected to be based on attributes of *key entities* and their interrelationships:

- current information about each student in that simulated classroom—student profile, current assessment log for that student, and where that student is located in his/her learning trajectory,
- qualities of each specific learning activity chosen for this move—according to empirical data on factors related to promotion of student learning,
- appropriate use of specific resources currently available (e.g., computers, calculators, textbooks, graphic calculators, math manipulatives, paper and pencil),
- amount of *teacher* time required by each learning activity,

- zone of proximal development with respect to the specific learning trajectory for each simulated student,
- individual differences in the simulated students and choice of respective learning activities that are best suited to each student's learning trajectory.

After each user move, the *SimTIE-Math* software will *then* execute the relevant "rules" of the simulation in order to generate outcomes based on these entities and their interrelationships. For example, if users choose activities that require more teacher time than is available, or which require resources that are not currently available, then those activities will not be "carried out" (time is wasted). Or, if the activity is too hard for a simulated student (i.e., too far away from his or her zone of proximal development, cf. Vygotsky, 1978), that student will not make progress towards the curriculum standard(s) associated with that learning activity. Highly important will be qualities of the chosen learning activities that are associated with First Principles of Instruction (cf. Merrill, 2002; Merrill, Barclay & van Schaak, 2008) and the 4C/ID Model (cf. van Merriënboer & Kirschner, 2007). Factors such as *authenticity* of the learning tasks (real-world tasks), teacher *activation* of student learning, *sequencing of learning tasks* from simple to complex, *supportive information* (e.g., conceptual models or schema), *just-in-time information* (e.g., demonstration of how to do the task), part-task *practice* (to achieve automaticity for skills), provision of *scaffolding* of learning (e.g., teacher feedback), and *integration* of what is learned into student lives. These factors have been shown empirically to be associated with promotion of student learning (cf. van Merriënboer & Kirschner, 2007). Persons who play *SimTIE-Math* will need to inductively learn to discriminate the presence and absence of these features of learning activities, and will be rewarded with more student learning progress when they choose activities that are rich with these qualities.

We will need to build algorithms which will make "realistic" predictions of outcomes of the selected learning activities with the simulated students with which a *SimTIE-Math* player is working. We expect to apply findings from research the Principal Investigator has been conducting on use of First Principles of Instruction, successful student engagement, and mastery of learning objectives (cf., Frick, Chadha, Watson, Wang, & Green, 2007; Frick, Chadha, Watson, & Zlatsovska, 2008). Empirically estimated probabilities associated with these patterns in these past studies will likely be incorporated into the prediction algorithms in the *Controller* logic. In addition, technology resources that a teacher has available in *SimTIE-Math* currently in his or her classroom—and a rating of the extent that the chosen activity could *not* be done as well *without* these information technology resources—will affect the outcomes of the selected learning activities. Most likely these ratings will be built into the game based on judgments from expert teachers (e.g., use of a scarce resource such as a computer when it does not really make a difference vs. use of a cheaper resource such as non-digital math manipulatives or simple pencil and paper). There will also be some random "chance" factors, such as a simulated student becoming ill, lacking enough sleep the night before, and distractions such as a fire drill or misbehaving peers.

Then a way of combining all this information is needed to "crunch the numbers" in order to predict the outcome of each learning activity with each simulated student. Here Bayesian Network Analysis (cf. Jensen & Nielsen, 2007; Neapolitan, 1990; 1991; Pearl, 2000) is likely to be useful for estimating the probability of student success, given the current conditions. For example, suppose that the BNA predicts that the probability of success is 0.60 and of failure is 0.40. A random number would then be chosen by the software from a flat distribution where each number between 1 and 100 is equally likely. If the selected number is between 1 and 60, then *SimTIE-Math* would determine that the learning activity was successful with that student; and otherwise it would not be successful if the number is between 61 and 100—thus mimicking the probability of that outcome occurring. This technique is similar to that used by Frick (1990), for dealing with probabilistic outcomes during Monte Carlo simulations of computer-adaptive tests, and subsequently used successfully in the digital version of the *Diffusion Simulation Game* (Frick, Kim, Ludwig, & Huang, 2003). These kinds of algorithms effectively implement Bayesian probabilistic reasoning (cf. Neapolitan, 1990; Pearl, 2000; Jensen & Nielsen, 2007), which stands in contrast to linear regression equations or algorithms that assume particular mathematical functions—e.g., item characteristic curves in item response theory (Lord & Novick, 1968).

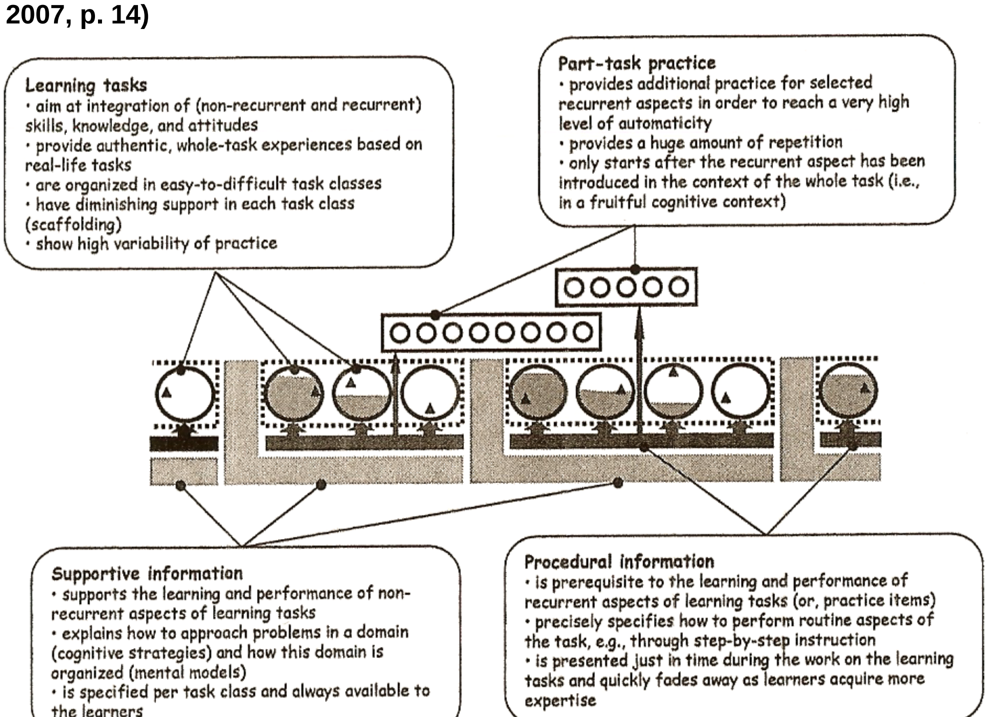
Modeling key entities and player record keeping. The *Modeling* part of *SimTIE-Math* MVC architecture is how the simulation-game state is maintained and updated continuously during play. Since *SimTIE-Math* needs to run on the Web, we expect that a database on a server (computer on the Internet) would need to be created. Not only would data that is part of the game itself be stored in the database, but also information would need to be stored about users who are playing *SimTIE-Math*, decisions they make and their outcomes, and specific game progress of each user. These records would not only be valuable for research purposes, but are necessary so that a player can "pause" the game, turn off his or her computer, and then "resume" at a later time, possibly on a different computer. Moreover, since these records would kept in a central database, loss of user data is expected to be minimal—since files would be regularly backed up automatically. The record of a player's decisions and the related outcomes could further be used for debriefing by the instructor and for recall and reflection by the player.

We expect to build *SimTIE-Math* using Flex Builder, ActionScript, PHP and MySQL so that it can be played online via a client-server interaction. The user's computer (the client) will do most of the work, while data are exchanged across the Internet with a server in the background. We have project personnel who are highly experienced and competent in using these software development tools.

2.2 R&D Design: Design Strategy for *SimTIE-Math*

The Four-Component Instructional Design (4C/ID) Model will be used in designing *SimTIE-Math* (van Merriënboer & Kirschner, 2007; van Merriënboer, Clark, & deCroock, 2002; van Merriënboer, Kirschner, & Kester, 2003). When preservice teachers learn to teach mathematics they are engaged in *complex learning.*

Figure 2. Blueprint for complex learning: 4C/ID Model (reproduced from van Merriënboer & Kirschner, 2007, p. 14)



Central to this model is the sequencing—from simple to complex—of *classes* of authentic, whole learning tasks. Each task class is represented in Figure 2 by a group of circles enclosed in a rectangle with a dotted border. Within a task class, the shading within each circle represents scaffolding for that task, which diminishes in subsequent tasks until the whole task can be performed without assistance. The small triangles within each circle represent variation of tasks within a task class. Note also the gray-shaded L shapes, which represent supportive information for non-recurrent aspects of tasks (including schema, cognitive strategies, etc.). Just-in-time (JIT) procedural information is also available for recurrent aspects of tasks; and part-task practice will also available to preservice teachers (the learners in *SimTIE-Math*) for aspects which require automaticity. The 4C/ID Model is consistent with extant research on how people learn (cf. Bransford, Brown, & Cocking, 2000; Donovan, Bransford, & Pelligrino, 1999), problems for understanding (Wiggins & McTighe, 2001), First Principles of Instruction (Merrill, 2002; Merrill, et al., 2008), learning trajectories (Clements, 2007), and whole-task-centered ID in contrast to topic-centered ID (Merrill, 2007).

The real-life tasks to be simulated here are preservice teacher selections of learning activities for the simulated students in the *SimTIE-Math* classroom (see Figure 1). The game will begin at Level 1 with the epitome task as Reigeluth (1999) recommends in Elaboration Theory (van Merriënboer & Kirschner's (2007) first task class). This is the simplest task which contains the most basic components of the whole task. Most likely this would be a task class in which the preservice teacher only needs to deal with a single student, one learning trajectory for that student (e.g., in learning numbers), and choosing from learning activities which are in one technology only (e.g., math manipulatives) for which the *SimTIE-Math* teacher is available the whole time. Considerable scaffolding would come from the *SimTIE-Math* mentor (see Fig. 1, upper left) by virtue of that mentor describing what the simulated student did during the activity. Profile information on that student would be restricted to the assessment log only (in Level 1). Supportive information would be excluded at this point (to decrease cognitive load), and game play would be limited to two weeks of learning activities. JIT information would be restricted to basic procedures necessary to operate *SimTIE-Math.* Within this task class, variation would be provided by choosing a different simulated student in each game play who has a different learning trajectory. Scaffolding by the mentor would also be reduced in subsequent plays at Level 1 until the preservice teacher can get his/her simulated student to increase learning achievement by *N* points in the assessment log within two weeks. Hence, the focus at the beginning level is to try to match the learning activity appropriately to the simulated student's specific learning trajectory—without thinking about other students, integration of technology, quality of the learning activity in terms of First Principles of Instruction, etc. When a teacher masters Level 1, then she or he advances to the next level (task class), in which one of the simplifying conditions is relaxed (Reigeluth, 1999). In other words, complexity will be a little greater at each level of *SimTIE-Math.* At the highest level of complexity, a preservice teacher will need to create and manage the mathematics learning environment for a whole class of 20-25 simulated students each with unique learning trajectories, in both numbers and geometry, for a whole "school year," with the whole gamut of information technologies available, and the entire very large set of learning activities to choose from in *SimTIE-Math*.

The range of learning activities in *SimTIE-Math* will likely be selected from Math Recovery (Cobb, Stafford, & Tabor, 2004), from the Building Blocks curriculum (Clements & Sarama, in press), from Singapore Math (1999), from several widely used K-6 textbook series in elementary mathematics, and from Montessori mathematics works (cf. Lillard, 2005). Furthermore, many activities will be modified to have several variations that include or exclude use of specific First Principles of Instruction (authenticity and wholeness of learner task, learner activation, demonstration, application, and learner integration).

2.3 R&D Design: *SimTIE-Math* Development Plan

Overview. During Years 1 and 2 we expect to iteratively design, develop and formatively assess computer prototypes following a design framework for complex learning (cf. van Merriënboer & Kirschner, 2007), understanding by design (Wiggins & McTighe, 2001) and a curriculum research framework (Clements, 2007). This approach is expected to lead to a production version of *SimTIE-Math* to be subsequently evaluated during Year 3 in teacher education mathematics methods courses at Indiana

University. During Year 4, summative evaluation of *SimTIE-Math* will continue, as preservice teachers do their student teaching in K-6 classrooms, in order to address the primary research questions.

Year 1. The first year of the *SimTIE-Math* project will build upon the research we have already done to identify relevant theories and empirical results—the *a priori* foundations and learning models specified by Clements (2007). We will focus on needs assessment and rapid prototyping (Tripp & Bichelmeyer, 1990) with usability testing. We will conduct focus groups with faculty and students in mathematics education about their practices and needs regarding individualized learning and technology integration. Our intent is to understand better how *SimTIE-Math* can be integrated with current teacher preparation, so that we may design supplemental teaching materials to support the use of *SimTIE-Math* and increase the probability of its adoption and implementation (Clements, 2007). We also want to understand how learning and performance in those areas is currently assessed so that we can design controlled experiments that compare outcomes of current instructional approaches with outcomes from instruction that utilizes *SimTIE-Math*.

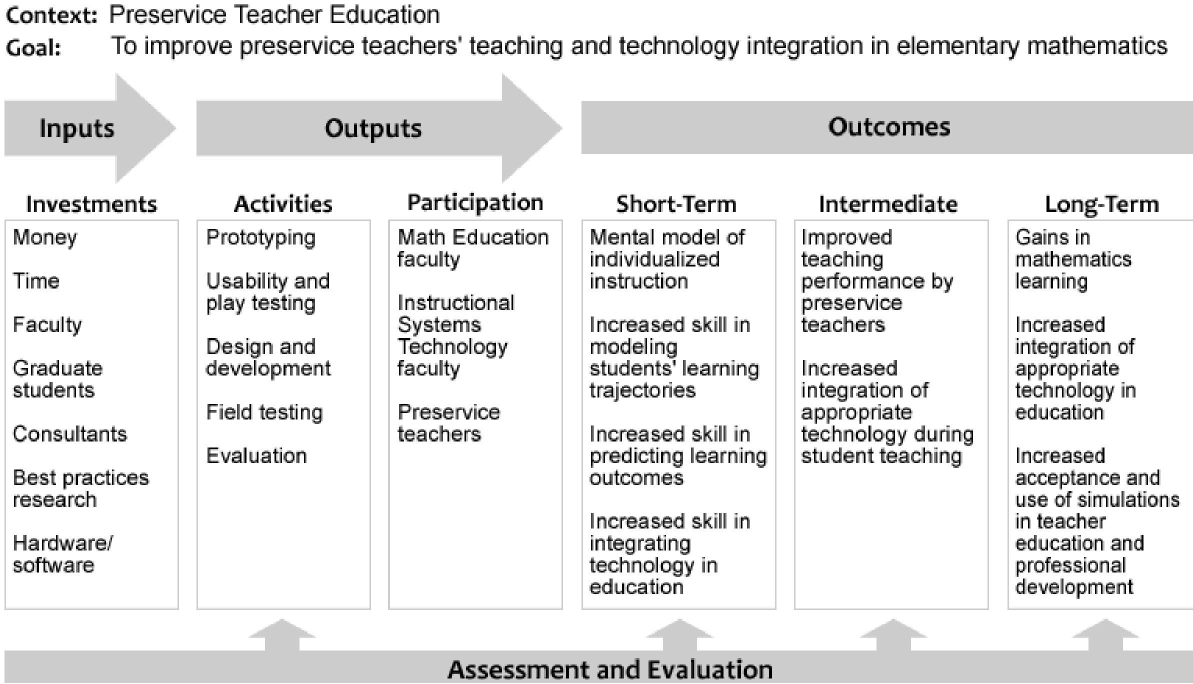
Simultaneously, we will continue our work on the rules and mechanics of the simulation-game and develop inexpensive paper prototypes (Snyder, 2003) that can be tested with members of our target audience using "discount usability engineering" techniques (Baek, Cagiltay, Boling, & Frick, 2008; Dumas & Redish, 1999; Nielsen, 1989). We will also begin content development/acquisition of virtual student profiles and the learning activities that players will choose for their virtual students. In the second half of the first year, we expect to undertake interaction design and the development of early digital prototypes for usability testing. Our programmers will begin database design and coding of the decision algorithms that will be the foundation for the simulation-game engine. In addition to being a repository of game content, the database will record players' decisions for review and analysis.

Year 2. In the second year, content development will continue as we apply instructional design theories (Merrill's First Principles and van Merriënboer's 4C/ID Model) to rate the learning activities. We will also continue rapid prototyping and usability testing, utilizing accepted methods such as the "think aloud protocol," audio/videotaping, screen capture, and "solution path recording" (Clements, 2007, p. 48) to understand how players are applying their pedagogical content knowledge to develop learning trajectories for their virtual students and form appropriate instructional strategies. One of our primary goals during this phase will be to identify the prompts or scaffolding strategies that are successful in getting students to use the tools and make good decisions. We will try to understand whether their actions are truly enactments of the desired cognitive operations or merely trial-and error. We will also recruit actual math teachers to evaluate the fidelity of the simulation-game with their real-world experience. As we approach a full working version, we will begin iterative play-testing focusing initially on player engagement (using eye-tracking and biometrics equipment in our User Engagement Lab in Informatics) and then on learning outcomes. These play-tests of *SimTIE-Math* will be monitored by the Center for Evaluation and Education Policy at Indiana University. We will also finish the development of curricular support materials and prepare for a year of field testing.

Year 3. The third year will consist of a field test during which *SimTIE-Math* will be used in several methods classes in the School of Education at Indiana University to evaluate the impact of the intervention. Our formative research methodologies will include ethnographic participant observation and interviews with participating faculty and preservice teachers. We will try to identify conditions that impact the effectiveness of *SimTIE-Math* and seek improvements to the supporting materials. Designers and programmers will continue to refine *SimTIE-Math* and implement new features based on feedback from participants and the results of evaluation.

Year 4. The fourth year will consist of further summative evaluation activities, described below. Figure 3 summarizes the Program Logic Model for the *SimTIE-Math* project, indicating where assessments and evaluation are planned.

Figure 3: *SimTIE-Math* Program Logic Model (note that Long-Term Outcomes will not be assessed in this project, but in a future proposal for subsequent field testing at other institutions)



3. Project Evaluation

Introduction. The Center for Evaluation and Education Policy (CEEP), Indiana University School of Education, will conduct an ongoing evaluation of the *SimTIE-Math* project. CEEP, with a three million dollar operating budget and more than four decades of experience in evaluation planning and execution, regularly conducts rigorous program evaluations on the national, regional and local levels. CEEP has over 60 Ph.D.-level researchers and support staff, including senior staff with expertise and experience in conducting evaluations in higher education. In addition to successfully implementing evaluations in over 35 states, CEEP has been working closely with the Office of Innovation and Improvement at the U.S. Department of Education to provide evaluation technical assistance to its grantees, and has been contracted by the National Center for Education Statistics to provide assistance in statistical and methodological design. CEEP's experience and advanced methodologies will lead to the development of measurable criteria and outcome-oriented data that will assist the program in making necessary adjustments throughout the project period and at its conclusions.

Evaluation plan. The evaluation will be implemented in a manner that provides on-going feedback for program improvement, as well as summative data related to program impact and outcomes. More specifically, the evaluation plan has three main goals: (1) To assess the quality and delivery of project activities, as planned (formative) and as implemented (summative), (2) To monitor the iterative development of the prototype, and (3) To assess measurable participant outcomes.
The goals/objectives will be monitored and measured to provide feedback to program administrators. Information gleaned from this ongoing monitoring process will then serve as the basis of a formative evaluation (or planning tool), on which continual program improvements can be based. Measurable program outcomes will also be monitored, analyzed, and reported to both program administrators and funders and will serve as the summative evaluation. Thus, this evaluation scheme will rely on the systematic collection and analysis of both impact and implementation data.

SimTIE-Math has set one overarching long-term goal for the program. It is: To improve preservice teachers' teaching and technology integration in elementary mathematics.

In order to evaluate the extent to which this goal has been accomplished the evaluation will have three main foci:

- Focus 1: To what extent is the prototype as developing and as implemented in Year 3 an asset to teachers' learning and understanding of teaching and individualizing mathematics instruction?
- Focus 2: To what extent does *SimTIE-Math* provide students with a realistic method of practicing the concepts they learn in class?
- Focus 3: To what extent are preservice teachers who use and have used *SimTIE-Math* for recommended time period better able to teach, individualize, and make appropriate decisions in mathematics instruction as student teachers?

Evaluation methodologies. Table 1 depicts the activities undertaken to accomplish the objectives, the measurable outcomes of the activities, and the evaluation methodologies that will be used to determine

Table 1. Evaluation Framework

Focus	Year	Evaluation Question	Method/Analysis
1	**1**	**To what extent is the prototype based on the needs of math teachers?**	**Teacher focus groups/surveys**
	1	**What changes need to be made to the prototype to make it more user-friendly and appropriate to the curriculum and state standards?**	**Project team interviews, tester feedback**
	2	**To what extent are the changes made in alignment with the recommendations made by current math teachers?**	**Project team interviews, tester recommendations**
	2	**To what extent do preservice teachers find the prototype engaging and usable?**	**Participant interviews/surveys**
	2	**To what extent do current math teachers find it to be a credible teaching tool?**	**Math teacher focus groups**
	3	**To what extent do preservice teachers find it easy to use? Engaging?**	**Participant/tester focus groups**
2	**3**	**To what extent to math ed professors find SimTIE to be a useful learning and practice tool?**	**Professor interviews**
	3	**Do participants in cohort 1 find it challenging and useful as a realistic practice device? Why or why not?**	**Participant interviews/surveys**
	3/4	**Do supervising teachers find their SimTIE student teachers to be better prepared? Why or why not?**	**Supervisor surveys**
3	**3/4**	**Is there a difference between preservice teachers who have used SimTIE and those who have not in their perceptions of readiness?**	**Supervisor surveys** **Participant surveys**
	3/4	**Is there a difference between preservice teachers who have used SimTIE and those who have not in their ability to individualize instruction?**	**Supervisor surveys** **Professor feedback**
	3/4	**Is there a difference between preservice teachers who have used SimTIE and those who have not in the appropriate decisions they make when teaching math during student teaching?**	**Supervisor surveys** **Professor feedback**
	4	**Are there any unintended outcomes of SimTIE outside of math instruction?**	**Observations** **Coursework** **Feedback tools**

success. This table outlines the substantive basis for the evaluation framework. The evaluator will also keep a close watch on the timeline to document whether or not benchmarks are being met. As shown in the method column of the chart, various quantitative and qualitative data will be collected and analyzed throughout each phase of the project.

The first two years of the project will be primarily formative as the focus will be on evaluating and improving the SimTIE prototype. The third year of the project will begin with a quasi-experimental design where students will either be placed in a mathematics method class where they use *SimTIE-Math* or where they do not, these students will form cohort one. The experimental group will be asked to play SimTIE a recommended period of time. Treatment fidelity will be measured through class and game playing observations, playing logs as maintained online, and surveys of both the experimental and control groups. The groups will be compared at the end of year 3 through their methods grades and other class grades and observations. This first cohort will then be followed into their student teaching experience. Supervising teacher observation data of the experimental group will be compared to data received from both the control group as well as to the results from the previous year's data. In addition professors from Indiana University will be asked to assess the readiness and ability of both groups. Finally cohort one students will be asked to complete a survey during at the end of their student teaching experience. A second cohort of students will enter the program during the fourth year. These students will also be assigned to use *SimTIE-Math* or not. Their course grades will be compared for the fourth year, but subsequent evaluations will depend on further funding of the project.

Deliverables. In addition to providing on-going formative feedback via e-mail, phone, and face-to-face discussions, CEEP will provide the project director and the advisory board with brief evaluation reports at the end of each semester on activities conducted that semester and at the end of the summer regarding summer activities. These reports will consist of a synthesis and summary of data collected during that time period, and where appropriate, a set of recommendations. CEEP will also produce annual evaluation reports for the duration of the grant. These reports will constitute a comprehensive assessment of the year's activities. The reports, data, and recommendations will be used to improve and strengthen the program. A final end-of-project comprehensive report of the program will be produced at the end of the funding period. This final report will be summative in nature and will discuss the extent to which the program was successful in reaching its goals and objectives.

3.1 Potential Advisory Board (to be invited to review our project annually)

- **Dr. Kyle Peck** (Penn State University, technology integration) or **Dr. Peg Ertmer** (Purdue)
- **Dr. Catherine Brown** (Indiana University, mathematics education)
- **Dr. Sivasailam Thiagarajan** (Darryl Sink & Associates, serious simulation and game designer)
- **Dr. Kurt Squire** (University of Wisconsin, serious simulation and game researcher)
- **Dr. Elizabeth Churchill** (Yahoo! Research, interaction design)

4. Project Dissemination Plan

We expect to present results of this project annually at national conferences (e.g., AERA, AECT) both during and after completion of this *SimTIE-Math* Project. We also expect to publish articles in both research and practitioner journals. Most important, however, is that dissemination of *SimTIE-Math* itself would be through the Web, once it is fully developed and evaluated. *SimTIE-Math* would "live" on a server at Indiana University. After the funded project is over, we plan to charge a small licensing fee to each *SimTIE-Math* user in order to defray costs of maintaining and updating this software on a central server and managing user support over time. We have done this successfully with the *Diffusion Simulation Game* (which has been online for about 5 years now, developed by the PI). To see how this works, go to the Google search engine and type "diffusion simulation game" in the search box.

Each user license would be associated with a unique user name (with a password) so that he or she can login and play *SimTIE-Math* as many times as wanted—anytime, anywhere. The primary advantage of such a planned dissemination mechanism is that any subsequent changes or modifications in *SimTIE-Math* are immediately available to all users—they will always have the most up-to-date version.

5. & 6. Expertise and Roles of Key Personnel (Including Results from Previous NSF Support)

Theodore Frick *(PI, Project Director):* Dr. Frick, a professor in the Instructional Systems Technology in the School of Education at Indiana University (IU), will direct this project. His seminal work and software development that used an expert systems approach to Bayesian reasoning in computer-adaptive testing was one of the earliest applications of what is now called computerized classification testing (Frick, 1990; 1992). He has more recently written software for analyzing system structure (MAPSAT), a form of network analysis based on digraph theory (Frick, et al., 2008). He has extensive experience in creating highly successful e-learning products, including the *Diffusion Simulation Game* and *Understanding Plagiarism* that have been used by millions of online learners in the past 5 years. As Web Director for the School of Education (1998-2005), he designed, developed and managed a large complex Website, supervised numerous content providers, and gained further expertise with advanced interactive Web technologies. He authored *Restructuring Education Through Technology* (1991) that provides the fundamental vision that underlies this proposal.

Enrique Galindo *(Co-PI, Mathematics Education)*: Dr. Galindo, a professor in the School of Education at IU, is a highly experienced mathematics educator. He will supervise the selection of mathematics learning activities for elementary students that are part of the *SimTIE-Math* simulation game and will coordinate use of *SimTIE-Math* in mathematics education courses. Dr. Galindo has directed many large-scale funded projects and has many years of experience with professional development. He has conducted research on learning in technology-supported environments, on the systematic development of educational multimedia products, on large-scale assessment and on teacher education. He directed the *Illuminations* and the electronic version of *Principles and Standards* projects, and was associate editor for the *Journal for Research in Mathematics Education*. He is currently a project director and co-PI on the NSF project Iterative Model Building (Grant 0732143).

Jeffrey Bardzell *(Co-PI, Interaction Design):* Dr. Bardzell, a professor in the School of Informatics at IU, specializes in human-computer interaction (HCI), online games, and experience design. Dr. J. Bardzell will assist with the simulation-game design itself—especially the computer interface and interaction design. He will also help supervise software development for *SimTIE-Math*.

Shaowen Bardzell *(Co-PI, Interaction Design & Play-Testing):* Dr. Shaowen Bardzell is a professor in the School of Informatics at IU, who specializes in HCI, affective computing, computer-supported cooperative work, and user engagement. She and Jeffrey have published books for Macromedia/Adobe on using Dreamweaver, Flash, Fireworks, etc. in developing e-learning products. Dr. S. Bardzell will coordinate *SimTIE-Math* play-tests in the *User Engagement Lab*, and conduct analyses of data on user engagement and motivation that is part of formative evaluation for improving the *SimTIE-Math* user experience. She will also assist with interaction design for *SimTIE-Math.*

Courtney Brown *(External Evaluation):* Dr. Brown is a senior research scientist at the Indiana Center for Evaluation and Educational Policy (CEEP). She will direct the external evaluation of the proposed *SimTIE-Math* project. She has extensive experience in past and current evaluations of NSF projects.

Rodney Myers *(Simulation-Game Design & Computer Database Design):* Rodney is a Ph.D. student in IST at IU, who brings over 20 years of experience in software development for the Web, has created games and simulations, and has produced award-winning films.

Miguel Lara *(Simulation-Game Logic & Computer Programming):* Miguel, also a Ph.D. student in IST, brings expertise in computer science (B.S. & M.S.) and software development for Web applications.

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