INTEGRATED MATH, SCIENCE, AND TECHNOLOGY IN THE MIDDLE GRADES

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Project Summary

This study will investigate the effectiveness of an interdisciplinary approach to teaching math, science, and technology, compared to a traditional disciplinary approach. The study will be conducted at a middle school in Tallahassee, Florida. Site demographics include percentages of African American and economically disadvantaged students above the district and state averages. A modified version of the Integrated Math, Science, and Technology (IMaST; Center for Mathematics, Science and Technology, 2004) curriculum will be the treatment condition. It will involve cross-disciplinary alignment among teachers and extensive use of applied learning activities and problem solving with the students. The comparison condition will be the business-as-usual math and science curricula (Glencoe). Math/science teacher teams will be the unit of assignment. In the within-subjects research design, instructional approaches will alternate each quarter. Student outcomes will include measures of math and science achievement, problem solving and higher-order thinking, and motivation and attitudes toward math and science. Growth trajectories will be used to determine if greater gains at each time point are associated with either instructional approach.

Rationale for the Study

The National Governors Association's (NGA; 2007) *Innovation America: Building a Science, Technology, Engineering, and Math* [STEM] *Agenda*, describes STEM-based instruction as follows:

> STEM literacy is an interdisciplinary area of study that *bridges* the four areas of science, technology, engineering, and mathematics. STEM literacy does not simply mean achieving literacy in these four strands or silos. Consequently, a STEM classroom shifts students away from learning discrete bits and pieces of phenomenon and rote procedures and toward investigating and questioning the interrelated facets of the world.
>
> One hallmark of a STEM classroom is an emphasis on design and problem-solving in "intellectually messy" learning situations that weave together the disciplines. . . . Thus, for example, a STEM classroom might pose a problem and then require students to do original research inspired by a classwide inquiry project, where they must use technology to gather and analyze data, design, test, and improve upon a proposed solution, and then communicate their findings to their peers in another country. (p. 7)

The call for curriculum integration within math and science reform springs largely from a constructivist perspective that cognitive and socio-cultural benefits derive from instruction that promotes applied learning and real-world problem solving (Loepp, 1999). Although strong philosophical support exists for integrating math and science as a means to improve student understanding and attitudes toward the disciplines, much more empirical work is needed to verify its effectiveness in producing such outcomes (2005; Berlin, 1991; Berlin & Lee, 2003).

The Integrated Math, Science, and Technology (IMaST; Center for Mathematics, Science and Technology [CeMaST], 2004) curriculum will be the treatment condition in the current study.

Satchwell and Loepp (2002) have evaluated IMaST's impact on student achievement. Although they were not able to rule out selection bias as an explanation for group differences, their study did justify further research on the curriculum's effectiveness.

Research questions

1. Can an integrated math and science curriculum that emphasizes applied learning improve students' scores on math and science achievement, better than current practices?

2. Can an integrated math and science curriculum that emphasizes applied learning improve students' performance on authentic assessments of mathematical and scientific proficiency, better than current practices?

3. Can an integrated math and science curriculum that emphasizes applied learning improve students' motivation and attitudes toward math and science, better than current practices?

4. What factors influence the effectiveness of such a curriculum?

Description of the IMaST Curriculum

Building on the National Research Council (NRC; 1999) report, *How People Learn*, the NRC (2005, 2007) identified the fundamental strands that constitute mathematical and scientific proficiency.

Strands of mathematical proficiency (NRC, 2005):
(1) *Conceptual understanding*;
(2) *Procedural fluency*;
(3) *Strategic competence*;
(4) *Adaptive reasoning*;
(5) *Productive disposition* (p. 218).

Strands of scientific proficiency (NRC, 2007):
(1) *Know, use and interpret scientific explanations of the natural world*;
(2) *Generate and evaluate scientific evidence and explanations*;
(3) *Understand the nature and development of scientific knowledge*; and
(4) *Participate productively in scientific practice and discourse* (p. 37).

The IMaST (CeMaST, 2004) instructional approach supports the attainment of these strands through the following:

The Challenge. Every module begins with a challenge. It is an integrated activity that introduces the overall module objectives and key concepts followed by a series of mathematics, science, and technology activities set in a learning cycle.

The Learning Cycle. The learning cycle in each activity comprises a four-phase instructional model having the following components: Exploring, Getting the Idea, Applying the Idea, and Expanding the Idea.

Making Connections. Each module has a component called Making Connections. To allow students to use their personal experience to construct their own knowledge, these readings are placed at the end of the activity. The Making Connections readings help students to expand and link what they are learning to real-world situations.

Concepts in Context. Gaining some insight into the module's key concepts by exploring them for a number of weeks, the Concepts in Context section helps students connect what they are learning to a broader social and environmental context. This section provides a broad context for the module theme.

Problem Solving using DAPIC [Define, Assess, Plan, Implement, Communicate]. Problem solving is a key instructional technique throughout the IMaST program. As students work to explore and solve the situations and problems presented to them in the learning cycle activities, they develop strong critical thinking skills such as predicting, hypothesizing, planning, controlling variables, analyzing, interpreting, and assessing.

Furthermore what the NRC (2005) denotes as *Procedural fluency*, *Strategic competence*, *Adaptive reasoning*, and *Productive disposition*, i.e., "skill in carrying out procedures flexibly, accurately, efficiently, and appropriately . . . ability to formulate, represent, and solve mathematical problems . . . capacity for logical thought, reflection, explanation, and justification . . . [and] habitual inclination to see mathematics as sensible, useful, and worthwhile" (p. 218), underpin every aspect of the IMaST curriculum. Only mathematical proficiency Strand 1, *Conceptual understanding*, stands out as a competency that could be attained, just as readily, through a traditional instructional approach.

The emphasis upon problem-solving and higher-order thinking within the IMaST (CeMaST, 2004) curriculum makes it a particularly appropriate intervention for Florida students. The Florida Department of Education (FLDOE; 2002) report, *Lessons Learned*, concluded that Florida students performed poorly on tasks that required them to disregard extraneous information, draw information from several sources, and solve problems that demanded persistence. The structural components of the IMaST curriculum that promote problem-solving and self-directed learning, and research indicating a pronounced positive effect on higher cognitive processes in science (Satchwell & Loepp, 2002) suggest that IMaST holds promise for increasing student depth of knowledge, one of the primary goals of Florida's revised math and science standards.

Sample

Fairview Middle School in Leon County, Florida, serves 845 students in grades 6-8 and has a high minority, low-income student population (62% African American and 52% economically disadvantaged) (Leon County Schools, 2006).

The current project will be implemented school-wide with Grades 6, 7 and 8, in both Pre-IB and regular classrooms. The Pre-International Baccalaureate (Pre-IB) program serves approximately one-third of the student body

Fairview Middle School's faculty are divided into nine teams: three teams at each grade level; of these three teams, two serve the general populations and one serves the students in the Pre-IB program. Each team comprises, at the minimum, a math, language arts, social studies, and science teacher, all of whom serve the same group of students. The present study will target the math/science pair in each team, as well as, the technology teacher, who is not associated with any team in particular.

Research Design

- **Within-subjects design**. The present study will primarily use a within-subjects design. The treatment condition (IMaST) and control condition (business-as-usual math and science curricula) will alternate each 9-week period, for every classroom. Thus, every student and teacher will interact with applied and integrated math and science for two nine week periods out of the year. This design was allow the researchers to analyze the data at the student level—and provide enough statistical power to detect curriculum effects. Furthermore, a within-subjects design eliminates the confound of equating treatment with treatment implementer. Students will be assessed for curriculum effects at the end of each quarter and data will be analyzed using growth curves.

- **Alternating sequence (between-subjects factor)**. Math/Science Teams will be randomly assigned to either begin the year with the *treatment* curricula—thus, following the pattern: *T – C – T – C*; or begin the year with the *control* curricula—thus, following the pattern: *C – T – C – T*. By varying the sequence pattern—to where some teams start the year with the treatment curricula and others start the year with the control curricula—we will increase the internal validity of the study, and thus, more effectively rule out the influence of historical events, e.g., hurricane days, on student learning. In addition, by combining this technique with a historical control we can be more confident that the observed growth trajectory does not represent peaks and plateaus of typical development.

- **Random assignment of students**. Students not in the Pre-IB program will be randomly assigned to one of the two general education classrooms in their respective grade level. Although this is not necessary for a within-subjects design, it will strengthen our ability to draw conclusions in the between-subjects factor (minimizing threats to internal validity). Since there is only one Pre-IB class for each grade level, random assignment of Pre-IB students is not possible.

- **Historical control**. Treatment will not begin until the 2008-09 school year, to allow time for alignment of the curricula and professional development. Quarterly assessments of students on the objective math and science tests and attitude/motivation scale will be conducted the year prior to treatment. This no treatment repeated measures historical control will help the research team understand the typical student learning growth trajectory, and strengthen our ability to draw conclusions about the impact of the treatment.

- **Treatment condition**. The year prior to the treatment year, key faculty at Fairview will examine the scope and sequence of the current math and science curricula, and determine which IMaST modules correspond to the benchmarks of the current curriculum in each nine week period. These selected modules will constitute the treatment.. During the treatment year and the prior summer, teachers will be presented with the specific modules that they will be teaching to their students and given adequate time to prepare lessons on each module. In addition to curriculum materials for IMaST (student textbooks and journals and teacher's resource editions), teachers will be provided with professional development to support the implementation of this new instructional method. Specifically, teachers will be introduced to the concepts of applied and integrated math and science instruction, and then to the particulars of the IMaST curriculum. Teachers who are working together as a team on IMaST modules will be given common planning time. The technology/computer teacher will be recruited to participate in the treatment as part of the team and will be eligible for the same training as math and science teachers.

- **Comparison condition.** The study will have a business-as-usual control group, which will be instructed using the school's existing curricula (Glencoe). To minimize treatment carryover effects (i.e., using the new IMaST instructional approaches during a control nine-week period) professional development will be provided to support the current curriculum . Carryover effects are particularly hard to avoid in a within-subjects design. Therefore, teachers will only be given access to the modules that they will be teaching and fidelity of implementation will be measured.by observation checklists containing content and instructional features of both IMaST and the current curriculum. The fidelity measure will be administered three times per nine weeks in every math and science classroom.

Student Outcome Measures

- **STAR Math Assessment**. The current study will use the STAR Math Assessment, which uses computer-adaptive technology, to monitor student progress in math achievement throughout the year.

- **PASS Science Assessment**. The current study will use the Partnership of the Assessment of Standards-based Science (PASS; 2007) Science Assessment as an objective measure of scientific proficiency. The PASS Assessment consists of Enhanced Multiple-choice Items; these components will be used to equate prospective performance against the FCAT science test, which is only given in the eighth grade. The PASS has been shown to possess a reliability coefficient of greater than $\alpha = .90$.

- **IMaST Performance Tasks**. These authentic assessments will be used as measures of applied mathematical and scientific proficiency and problem solving efficiency.

- **Science Olympiad**. These authentic assessments will be used as measures of applied mathematical and scientific proficiency and problem solving efficiency.

- **IMaST Science Writing Task**. IMaST emphasizes the use of writing to communicate scientific information. Performance on these tasks can be analyzed for indications of student development toward mathematical and scientific proficiency.

- **Motivation, attitudes, and identity assessment**. A quarterly student survey will be administered to monitor student beliefs about science and identities as learners. It will identify three constructs described by the NRC (2007) as the factors of active engagement and productive participation: Beliefs about oneself and about science ("I can do science"); Goals, values, and interests ("I want to do science"); and Identity ("I belong") (pp. 194-202). The assessment of these factors may serve as a measure of progress toward the CEOSE (2006) mission of increasing the participation of underrepresented populations in STEM occupations. The research team is investigating the literature to locate an instrument that has established reliability and validity. If one is not located, one will be developed.

Fidelity of implementation

A fidelity measure of the primary treatment components will be developed. It will consist of observation checklists measuring student academic behaviors and teacher instructional and assessment procedures espoused by IMaST. It will include features of the curriculum such as writing/journaling, hands on activities, problem-solving, the use of technology, and the integration of cross-content material, e.g., reinforcing math concepts in a science classroom. The fidelity measure will be administered three times per nine weeks in every participating classroom by a research assistant. An additional fidelity measure will be a teacher survey of instructional practices that correspond to the features of the IMaST curriculum.

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