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Online instruction about integration of science and mathematics with middle-grades teachers: Four years in and aiming for sustainability

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ABSTRACT

The purpose of this article is to illustrate the model used to develop an online graduate program called iSMART (Integration of Science and Mathematics and Reflective Teaching) and discuss the changes made in the program over the past 4 years. Starting in 2009 as its preparation year, iSMART is a unique project aimed to provide an online master's program for middle-grade science and mathematics teachers in Texas and is currently working with its 4th cohort of teachers. The authors identify the necessary infrastructure and provide examples for others to consider as they take on similar challenges in developing sustainable online programs with practicing science and mathematics teachers.

1. Introduction

Online courses and programs have emerged as widespread venues of delivering instruction for institutions of higher education (Allen & Seaman, 2013), and are beginning to emerge in teacher professional development (e.g., Dash, deKramer, O'Dwyer, Masters, & Russell, 2012; Groth & Burgess, 2009; Koc, Peker, & Osmanoglu, 2009; Silverman & Clay, 2010). Furthermore, international and national organizations in science and mathematics education such as the *International Council of Associations for Science Education*, *National Science Teachers Association*, and the *National Council for Teachers of Mathematics* advocate the integration of science and mathematics. Despite such heavy advocacy, there are a variety of definitions of what science–mathematics integration actually means (Hurley, 2001; Lederman & Niess, 1997).

Consistent with these trends, in 2009, the authors and their colleagues[1] were charged with the task of designing and implementing a 2-year online master's program for middle-grade science and mathematics teachers. This uniquely designed program, Integration of Science and Mathematics and Reflective Teaching (iSMART), focused on the integration of science and mathematics as a means to further develop teachers' content and teaching knowledge as well as support the development of teacher leadership and technology skills.[2] The social constructivist theoretical framework of the program and the design-based research behind the development decisions were discussed in earlier publications (Lee, Chauvot, Plankis, Vowell, & Culpepper, 2011; Lee, Chauvot, Vowell, Culpepper, & Plankis, 2013). The first cohort of 25 science and mathematics teachers began the 2-year program in fall 2010; subsequent cohorts of 22–27 teachers have been enrolled each year. To date, 66 (of 69) teachers have graduated from the program and 26 more teachers are currently enrolled in the program. All of the participating teachers were/are teaching full time while enrolled in the program, and had been teaching at least 3 years when they started in the program.

The purpose of this article is to illustrate the model used to develop the program and discuss the changes made in the program over the past 4 years. Importantly, we identify the necessary infrastructure for others to consider as they take on similar challenges in developing sustainable online programs with practicing science and mathematics teachers. This account is generated by reviewing over fifteen reports submitted to the funding agency regarding progress toward specified outcomes as well as multiple email correspondences and interviews with the director of the program. Whereas the director of this program is the first author, the second author conducted the interviews and prompted the email correspondences.

2. Aiming for sustainability: challenges and revisions

In developing and evaluating the iSMART model, we have used a design-based research methodology. This approach is in line with our theoretical framework of situated cognition (Brown, Collins, & Duguid, 1989; Cognition & Technology Group at Vanderbilt, 1993; Lave, 1988; Lave & Wenger, 1991).

2.1. Design-based research

Design-based research is known for incorporating both empirical educational research and theory-driven design of learning environments in

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order to move beyond the simple sequencing of the design and evaluation of a particular intervention (The Design-Based Research Collective, 2003). Design-based researchers promote research that takes place in the real-world or authentic settings. When effectively employed, the research results inform practice.

Such a framework has proved highly valuable in the evolution of the integrated and complex aspects of the iSMART program. With the emphasis on research embedded in authentic settings, the iSMART faculty have consistently focused on understanding how iSMART teachers define two key aspects of the program: (1) student-centered instruction in middle-school science and mathematics, and (2) the integration of the two subject matters. Also, as teacher educators, iSMART instructors are investigating how this kind of teacher education can be translated and delivered in an online learning environment. Additionally, the iSMART instructors and designers are looking for ways to scale this to a larger audience in a sustainable way. As an inquiry paradigm, the design-based research methodology can "incorporate various methodologies that can reveal the connections between the implemented practice and any theory building that is contextualized within the practice" (Lee et al., 2011. p.192).

In this project, we used the design-based research framework proposed by Reeves (2006). The following section illustrates the four iterative phases of Reeves' model (Amiel & Reeves, 2008; Reeves, 2006) and how the phases were used in the design and implementation of the iSMART project.

2.1.1. Phase 1: analysis of practical problems by researchers and practitioners in collaboration

- The review of literature pointed to the need for integration among disciplines to better serve the students (Dewey, 1933) as well as provide instruction in the authentic contexts (Ronis, 2007; Roth, 1993).
- The teacher educators and instructors of the iSMART program had previous experiences teaching in middle-school science and mathematics. As with the prevailing literature, these real-world practitioner experiences and perspectives also supported the need for integrated instruction and hands-on learning experiences for the teachers.
- Based on the above issues and findings, a possible solution was identified. More specifically, an idea of providing integrated instruction in science and mathematics for middle-school teachers throughout the state of Texas received funding from a state foundation focused on educational issues. With the funding in place, an online platform was selected in order to reach these middle-school teachers in various locations across the state.
- As part of this process, the following research question was generated: how can one design and implement an online program for middle school mathematics and science teachers in Texas that provides highly integrated instruction situated in authentic learning environments?

2.1.2. Phase 2: development of solutions informed by existing design principles and technological innovations

- Based on the analysis of the problem identified by literature reviews and extensive experiences as practitioners, a 2-year master's program for middle-school science and mathematics teachers was designed and delivered entirely online.
- The current teacher educators in the two subject areas as well as an instructional technology faculty member have collaborated in the design and the development of the program. The end result was that the math education and science education courses were offered separately but in an integrated way.
- An important aspect of the program was its mandatory synchronous class meetings. That particular decision was based on the program's theoretical framework employing situated cognition which included the use of hands-on lessons.

2.1.3. Phase 3: iterative cycles of testing and refinement of solutions in practice

- The implementation of the program and subsequent 4 years of testing and refinement of solutions in practice are illustrated in detail in the following section of this paper.

2.1.4. Phase 4: reflection to produce "design principles" and enhance solution implementation

- The members of the iSMART project team have held regular meetings for the last 4 years in which the weekly reports and student issues were discussed. The ideas and suggestions from these meetings were then implemented in the following classes.
- The cohort system of the iSMART facilitated the collective reflection process among its members as well as between those of the different cohorts.

The two most unique, and, therefore, challenging aspects in this project were to figure out how to deliver the program completely online and then to decide the content of courses that needed to focus on science–mathematics integration at the middle grades. Historically, science and mathematics teacher educators model best practices in face-to-face university classrooms and in professional development sessions as a way to teach about learner-centered instruction with children. Theoretically, a model for how to teach teachers in an online environment about face-to-face learner-centered instruction was needed; we feel that we have developed such a model. Pragmatically, it was necessary to identify/train instructors who could deliver content in an online environment in ways that would still model best practices of face-to-face instruction with children and produce the desired outcomes of improved content knowledge and improved instructional practices of the teachers in the program.

The second main challenge was to design a program that focused on science–mathematics integration, a construct that is loosely defined in the literature. Over the 4 years, we have identified different kinds of enactments of integration that grew from our initial interpretations of science–mathematics integration and our attempts to put our interpretations into practice. In hindsight, we have realized that these enactments of such integration are a testament to what one might expect in developing programs that require genuine collaboration across two or more disciplines. Success is also dependent on a clear and viable working model that addresses online instruction of teachers in a master's degree program.

2.2. Program coursework and activities

The current degree plan and overview of the program activities are illustrated in Fig. 1. The illustration suggests a list and sequencing of discrete courses and learning experiences. To the contrary, the central themes of integration, learner-centered instruction, equity, technology, and reflective practice are threaded across all of the iSMART courses. Whereas Cohorts 3 and 4 followed the sequence of coursework and activities reflected in Fig. 1, Cohorts 1 and 2 experienced several variations from the original program design. These variations, the reasons for the changes, and anticipated upcoming changes will be shared in a subsequent section of this paper.

The intent of the face-to-face orientation that takes place during the summer before coursework begins is to initiate the development of relationships between teachers within the cohort and the faculty members who will be the instructors in the upcoming years. Activities during this orientation include team-building activities. The orientation also provides workshops on how to use the technology that is required during the synchronous instruction of the upcoming semesters (i.e., Wimba Live Classroom or Blackboard Collaborate).

The first semester of the program is a deliberate focus on instruction and pedagogy in science and mathematics classrooms. The second semester, in contrast, steps back to examine broader issues in science