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Developing instructor support materials for an inquiry-oriented curriculum

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ABSTRACT

The purpose of this paper is to describe the process of designing web-based instructor support materials for an inquiry oriented abstract algebra curriculum. First we discuss the ways in which the research literature influenced the design of the instructor support materials. Then we discuss the design-based research methods used to develop the instructor support materials, elaborating the ways in which the research phases of our work contributed to the design of the instructor support materials. This discussion includes specific examples of important insights from our research and precisely how these were incorporated into the support materials.

1. Introduction

In recent years reform-oriented mathematics curricula have become increasingly prevalent, gaining attention among policy-makers and enjoying, in some instances, widespread implementation. This has occurred primarily at the K-12 level, with school districts across the country using curricula such as Investigations (TERC, 1995) and the Connected Mathematics Project (Lappan, Fey, Fitzgerald, Friel, & Phillips, 1998). There have also been innovations of this type in undergraduate mathematics instruction, including the Harvard Calculus program (Calculus Consortium at Harvard, 1994) and Henderson's 'Experiencing Geometry' text (Henderson & Taimina, 2004).

Recently, a number of researchers have conducted instructional design studies aimed at leveraging the theory of Realistic Mathematics Education (RME) for supporting the learning of undergraduate mathematics. There are ongoing RME-guided instructional design projects at the undergraduate level in the areas of differential equations (Rasmussen, 2007), abstract algebra (Larsen, Johnson, & Bartlo, 2013), and advanced calculus (Oehrtman & Swinyard, 2011). These studies are resulting in innovative student-centered instructional approaches that place significant demands on instructors in terms of making sense of and leveraging students' thinking to advance the instructional agenda (Johnson & Larsen, 2012; Speer & Wagner, 2009).

The process of scaling up these innovations to serve a wider audience is a significant challenge but is necessary if such innovations are to have a real impact on STEM (Science, Technology, Engineering, and Mathematics) education. The National Science Foundation calls for such work in its solicitation for the TUES (Transforming Undergraduate Education in Science, Technology, Engineering, and Mathematics) program:

> This solicitation especially encourages projects that have the potential to transform the conduct of undergraduate STEM education, for example, by bringing about widespread adoption of classroom practices that embody

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Table 1
Project activities featuring data collection.

Year	Stage	Activity	Units
2002	1	Sequence of Three Small-Scale Design Experiments (*7–8 90-minute sessions w/two students*)	Group & Isomorphism
2004–2005	2	Experimental Teaching in Group Theory Course w/Designer as Teacher (*approx. 30 students for 10-week course*)	Group & Isomorphism
2005	2–3	Teaching Experiment in Algebra Course for K-12 Teachers (*10 2-hour sessions with 4 sections of 15–24 teachers*)	Group & Isomorphism
2006	1	Small-Scale Design Experiment (*10 90-minute sessions with two students*)	Quotient Groups
2007	2–3	Whole Class Teaching Experiment w/Mathematician as Teacher (*approximately 35 students for 10-week course*)	Full Curriculum[a]
2008–2009	3	Implementation by Three Mathematicians w/Limited Support – Instructor Notes & Email Conversations (*each approximately 35 students for 10-week course*)	Full Curriculum
2011	3	Implementation by a Mathematician at a Different University w/Only Web-Based ISMs for Support[b] (*approx. 30 students for 15-week course*)	Full Curriculum

[a] Debriefing/planning video for full course + classroom video for *quotient groups* only.
[b] Data include smart board video capture and audio recordings of class sessions.

understanding of how students learn most effectively. Thus transferability and dissemination are critical aspects for projects developing instructional materials and methods and should be considered throughout the project's lifetime (National Science Foundation, 2011, p. 4).

The primary goal of the *Teaching Abstract Algebra for Understanding* (*TAAFU*) project has been the scaling up of an RME-based group theory curriculum, which we refer to as the TAAFU curriculum. This curriculum was developed through a series of design experiments (Design-Based Research Collective, 2003) and has been refined through several iterations of classroom trials. More recently, a number of mathematicians (who were not involved in the development of the curriculum) have implemented the curriculum. The experiences and backgrounds of three of these mathematicians are discussed in detail in Johnson, Caughman, Fredericks, and Gibson (2013).

The process of scaling up to include instructors not involved with the creation of the TAAFU curriculum has motivated us to design Instructor Support Materials (ISMs) to support teachers in successfully implementing the curriculum. These ISMs take the form of an interactive website that provides instructors with a number of resources to help them implement the curriculum effectively and faithfully.

The purpose of this paper is to describe the process of designing our ISMs. First we discuss the ways in which the research literature influenced the design of the ISMs. Then we discuss the design-based research methods used to develop the ISMs. Finally, we discuss the ways in which the research phases of our work contributed to the design of the ISMs. This discussion includes specific examples of important insights from our research and precisely how these were incorporated into the support materials. Before we describe our design process, we briefly describe the TAAFU curriculum and the ISMs that we have created.

2. Overview of the TAAFU curriculum and instructor support materials

The development of the TAAFU curriculum and the accompanying ISMs was a multi-year, multi-stage project. Table 1 provides a timeline of the primary project activities that featured data collection. All small-scale design experiments were video-recorded using one camera and (unless otherwise noted) all classroom activity was recorded using two cameras to capture video of small group and whole class activity.

2.1. The curriculum

The TAAFU curriculum is a research based, inquiry-oriented abstract algebra curriculum that actively engages students in developing the fundamental concepts of group theory. The *TAAFU* curriculum was primarily designed to be used in an upper-division, undergraduate abstract algebra course and is composed of three primary units: groups/subgroups, isomorphisms, and quotient groups. Each unit begins with a *reinvention phase* in which students develop concepts based on their intuition, informal strategies, and prior knowledge. The end product of the reinvention phase is a formal definition (or definitions) constructed by the students and a collection of conjectures. The deductive phase begins with the formal definitions that are relevant to the concept. During this phase, students work to prove various theorems (often based on conjectures arising during the reinvention phase) using the formal definitions and previously proved results. For a detailed description of the curriculum please see Larsen et al. (2013).