PARTICIPANT RESEARCH ESSAY
FOR TTAME RESEARCH TEAM

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The term Dynamic Geometry (DG) refers to active geometric explorations carried out with interactive computer software such as the Geometer’s Sketchpad (Jackiw, 2009) or Cabri Geometry (Texas Instruments, 1994), which has been available since the early 1990’s. Along with the widespread use of DG software, many related research studies on the DG approach—an approach to high school geometry that utilizes DG software to supplement ordinary instructional practices—have been conducted. A relatively small group of researchers (e.g., Dixon, 1997; Gerretson, 2004; Myers, 2009) have used experimental or quasi-experimental designs in their studies. Most of the studies (e.g., Choi-Koh 1999; Hannafin, Burruss, & Little, 2001; Hollebrands, 2007; Vincent, 2005) used qualitative research methods.

My main research interest is on the use of technology tools in mathematics education and its impact on students’ mathematics learning. Over the years, I have worked with pre-service mathematics teachers and middle/high school students closely on using technology tools including DG software to facilitate their mathematical explorations. Collaborating with my colleagues, I discussed how the DG learning environment was based on the constructivist theory of learning, and investigated if and how the use of the Geometer’s Sketchpad (GSP) helped our students advance their van Hiele (1986) levels of geometric thinking and improve their mathematical reasoning and proof abilities. Specifically, in a study on the use of GSP on two college pre-service teachers (Jiang, 2002), I found that GSP worked differently with each individual student. What the students discover through the use of GSP is dependent on the students’ abilities. I also discovered that GSP was an extraordinary tool that enhanced students’ ability to write proofs and increased their reasoning in mathematics.

In a 4-year study with a group of 24 low-socioeconomic, middle/high school minority students (McClintock, Jiang, & July, 2002), through the use of GSP activities related to three-

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dimensional visualization, observations on how students constructed dynamic GSP representations to conduct geometric investigations, and interviews with students as they solved challenging geometry problems, we found that GSP provided opportunities to have a distinct positive affect on students’ learning of three-dimensional geometry. With their continuous efforts, the students’ geometric thinking increased on average two van Hiele levels. In related work (Jiang & McClintock, 2000; Jiang & McClintock, 1997), we discovered that as they explored geometry problems with DG software, the preservice teachers developed a new learning style - exploring problem situations through a learning process characterized by initial conjecture – investigation – more thoughtful conjecture – verification (or proof) – proof (or verification). In addition, innovative technology tools in mathematics education such as GSP, featuring multiple, linked representations, have greatly enhanced the students’ potential to develop multiple solutions to various problem situations (Jiang & McClintock, 2000).

According to the research studies described above, if DG software is used effectively, it can make significant difference(s) in students’ learning; when used as a cognitive tool, it can facilitate students’ exploration and investigation activities, promote their conjecturing, verifying, explaining, and logical reasoning spirits and abilities, and enhance their conceptual understanding of important geometric ideas. However, almost all of the studies were either exploratory phenomenological studies that involved a small number of participants, or comparative studies that were conducted during a relatively short period of time, which may potentially limit the findings.

Based on these considerations, most (if not all) of the studies mentioned above need careful replication and amplification (Jones, 2005). DG software, though very widely used, has not been rigorously evaluated. The need for achieving a more thorough understanding of the power of DG software is clear.

**Research Questions and a Four-Year Research Project Funded by NSF**

The questions that I am interested in researching include: 1) How do students taught in a DG oriented instructional environment perform in comparison with students in the control condition on measures of a geometry standardized test and a conjecturing-proving test? 2) How does the DG intervention affect student beliefs about the nature of geometry and their beliefs about the nature of mathematics in general? 3) How does the DG intervention contribute to narrowing the achievement gap between students receiving free or reduced price lunch and other students? 4) How is students’ learning related to the fidelity and intensity with which the teachers implement the DG approach in their classrooms? and 5) What characterizes the learning communities in the experimental and control classes?

A research project designed to investigate these research questions has been funded by the National Science Foundation. The research project includes repeated randomized control trials of the DG approach. The primary goal of the project is to examine the efficacy of the DG approach on students’ geometry learning over the course of a full school year. The general plan for the four-year project is as follows: Year 1: Preparation (All research instruments, recruitment of participants, professional development training and resource materials, etc.); Year 2: The first implementation of the DG approach, and related data collection and initial data analysis; Year 3: The second implementation of the DG approach, and related data collection and continued data analysis; and Year 4: Careful and detailed data analysis and reporting. The study is presently in progress during project year 2.

An integrative framework (Olive & Makar, 2009) drawing from Constructivism, Instrumentation Theory and Semiotic Mediation is used to guide the study. Central to Instrumentation Theory “is the process of Instrumental Genesis – How a tool changes from an
artifact to an instrument in the hands of a user, and how both the tool and user are transformed in the process” (Olive, 2011, p.2). The notion of *semiotic mediation* was introduced by Vygotsky (1978). According to this notion, cognitive functioning is closely linked to the use of signs and tools, and affected by it. Olive and Makar (2009) focus on the mathematical knowledge and practices that may result from access to digital technologies. They put forward a new tetrahedral model that integrates aspects of instrumentation theory and the notion of semiotic mediation. “This new model illustrates how interactions among the didactical variables: student, teacher, task and technology (that form the vertices of the tetrahedron) create a space within which new mathematical knowledge and practices may emerge” (Olive, 2011, p.3).

**Research Design**

The population from which the participants of this study were sampled are the geometry teachers and their students at the high schools in Central Texas. Based on a power analysis to determine the optimal sample size and taking attrition into consideration, 76 geometry teachers were selected from those who applied to the project with support from their principals.

The research study followed a mixed methods, multi-site randomized cluster design, with teachers as the unit of randomization. The 76 teachers selected were randomly assigned to the Experimental Group and the Control Group. For schools where the selected teachers teach more than one class, only one class per teacher was randomly chosen to participate in the study. Therefore each teacher is represented in the study with measurements from only one classroom of students, and the classroom and teacher unit of analysis overlap, yielding the design where the students are nested within teachers/classrooms, which are nested within schools.

Student learning was assessed by a geometry test, a conjecturing-proving test, and a measure of student beliefs about the nature of geometry. Teachers in both treatment and control groups received relevant professional development. To determine how to capture the critical features of the DG approach, we have designed measures of fidelity of implementation - a DG implementation questionnaire and a classroom observation instrument. To probe more deeply into the teachers’ and students’ thinking processes, and to gather evidence about the range and variability of participants’ development of the most important abilities that the DG approach fosters, this study utilized in-depth interviews with selected students and teachers.

The project team has completed its first implementation of the DG approach and related data collection. Some initial data analysis (mainly the psychometric analysis on the project-developed instruments) has been conducted, but the primary analysis of the collected data is still on going and will be conducted during project year 3.

For all project-developed measures, the Cronbach’s Alpha statistical values are within the acceptable ranges for reliability. Other psychometric properties were examined for some of the instruments and provide evidence supporting the validity of each.

The principal method of data analysis will involve fitting a three-level hierarchical linear model (a linear mixed effects ANCOVA model) to the data using HLM V6.02 software (Raudenbush, et al., 2004). This multilevel approach also enables us to address research question 3, examine the potential treatment effect with respect to the ethnic, socio-economic, and linguistic characteristics of the students and the demographic composition of schools, and explore the potential of the DG learning environment for reducing the achievement gap.

Qualitative data analysis will use the constant comparative approach (Glaser & Strauss, 1967) to answer research question 5. The quantitative data analysis and the qualitative data analysis reported above, as a whole, will answer research question 4 that relates to implementation fidelity.

Guided by the theoretical framework described above, in the data collection and analysis
processes, we pay close attention to the interactions among teachers (including the researchers),
tasks (the conjecturing/proving tasks presented to the participating teachers or students), tech-
nology (GSP tools) and students. These interactions brought forth new mathematical thinking
of the participating teachers and students through the processes of instrumental genesis and
semiotic mediation (Olive, 2011).

Beyond the Current Project

The current project is expected to provide strong evidence of the efficacy of the DG approach as
implemented on a moderately large scale. Based on this, after the current project is completed,
we will be ready to collaborate with researchers at other universities (ideally members of the
WISDOMc program) to develop a scale-up project that will involve a larger sample in different
geographical areas with sufficient diversity in schools, classrooms, or students, to explore
whether the DG approach produces a net positive increase in student learning and achievement
relative to the comparison group that does not use computer exploration/drawing tools or may
receive whatever programs and practices are already currently available and utilized by schools
(US DOE, 2010). As many researchers (e.g., Artigue, 2000) have pointed out, the question is not
only which is best, but also how the DG approach is different and what the epistemic differences
are. Therefore, the new project, as the current one, will have a strong qualitative component
concentrating on developing new insights related to the ways of thinking and communicating
that are characteristic of the DG environments.

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