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## Using IGS Strategically to Support Students' Thinking

### Introduction

*Principles to Actions: Ensuring Mathematical Success for All* (NCTM, 2014) identifies teachers' ability to implement tasks that promote reasoning and problem solving as one of eight mathematics teaching practices. Research corroborates this practice, demonstrating students' mathematical thinking has important implications for student learning (Stein & Lane, 1996). Furthermore, tasks starting at a low level during set up typically stay at a low level during implementation (Stein, Grover, & Henningsen, 1996). Thus, an important issue in teacher education is supporting teachers in their ability to select, modify, or design high-level tasks to implement with their students.

This teaching practice complements the mathematical practice of using appropriate tools strategically (CCSS, 2010). In particular, teachers must be discerning users of technology to create and implement technology based tasks to effectively support students' reasoning and problem solving. The first two authors (2015) developed a practical tool to support mathematics teachers in assessing the role of technology in a task, and analyzing how it supports students' mathematical thinking (referred to as the IGS Framework). This paper reports on teachers' use of the IGS Framework to create IGS tasks that support students' high level mathematical thinking.

### Perspectives

Interactive geometry systems (IGS) support the learning of important mathematics (Hollebrands & Dove, 2011) and students' mathematical thinking (Sherman, 2014; Cayton, 2012). Yet an important principle of using technology strategically for mathematics instruction is that the inclusion or exclusion of technology within a given task depends on the mathematical goals of the task. The IGS Framework (Figure 1) combines Sinclair's (2003) design principles and Pea's (1985) metaphor for technology use as an *amplifier* or *reorganizer* along three mathematical dimensions. Each dimension (row) represents a distinct but not mutually exclusive mathematical goal. For each goal use of technology as an amplifier or a reorganizer in relation to that goal is described.

| | | Technology Used As | |
|---|---|---|---|
| | | **Amplifier**<br>Students could achieve the same goal without the technology | **Reorganizer**<br>The mathematical goal of the task would be difficult to achieve without DGS |
| **Goals** | **Question** | **Use of Design Principles** | |
| Make mathematically meaningful observations; look for invariant relationships. | Do the sketch and prompts use the dynamic affordances of DGS in a way that would be difficult or impossible to replicate without it? | Students create multiple static examples, either by construction or dragging, and reason from those static examples, e.g., students are prompted to make observations or generalizations based on a table or static measurements without reference to the sketch. | The sketch allows for continuous dragging, and students are guided to examine measurements or relationships dynamically. Students are required to make or explain observations or generalizations dynamically in terms of the sketch. |
| Mathematical exploration; use appropriate tools strategically. | How does technology support mathematical exploration? | Sketch and prompts guide students to investigate the same example or set of examples to explore mathematical connections or invariances. Freedom with respect to dragging does not provide alternative paths if students are all investigating the same example. | Sketch and prompts allow students to explore based on individual observation of mathematical concepts, connections or invariances within the sketch. The sketch supports students' mathematical exploration by providing alternate paths. |
| Make and test conjectures; modify thinking; foster curiosity. | Does the sketch provide feedback? Do the prompts encourage or require students to use feedback? | Sketch is limited by restrictive construction or does not provide feedback to allow students to explore their conjectures. Prompts do not explicitly guide students to test conjectures. | Sketch provides feedback or allows students to test and refine conjectures. Prompts explicitly guide students to use the sketch to test conjectures. |

Figure 1: IGS Framework (Sherman & Cayton, 2015)

A separate line of research highlights teachers' difficulty selecting and implementing high cognitive demand tasks (Stein, Grover, & Henningsen, 1996), but also teachers can grow in this area of their practice through carefully designed professional development (Boston & Smith, 2009). Importantly, tasks that are considered low-level as written are rarely implemented at a high level (Stein et al, 1996; Stein & Lane, 1996). This underscores the importance of supporting teachers in selecting, revising, and designing high-level tasks. The present work adds a focus on leveraging the affordances IGS to the work of Boston and Smith to support the high level thinking required by the task. The framework serves as a practical tool to support teachers in assessing how the use of technology supports particular goals for students' thinking and reasoning, and to suggest ways in which a task might be revised in order to accomplish certain goals more effectively

## Research Question and Methods

This study was the culmination of work developing the IGS framework (Sherman & Cayton, 2015) and a sequence of activities designed to support teachers in learning to use it to evaluate, revise, and design tasks that make use of IGS to support students' high level thinking (Sherman, Cayton, & Chandler, 2015). The research questions we posed were:

1. Can teachers use the IGS Framework to create tasks that use IGS as a reorganizer along at least one of the dimensions?
2. Does the use of IGS Framework support teachers in creating high-level tasks?

*Context and Sample*

Participants included 23 teachers at a Midwestern university enrolled in a course aimed at helping teachers integrate technology into mathematics instruction. Twenty-two were pre-service teachers, 15 were enrolled in an elementary certification program, and the remaining 8 were middle/secondary.

Prior to creating tasks utilizing the IGS Framework, participants were introduced to its theoretical underpinnings, analyzed three tasks, and revised a task that was initially characterized as an amplifier along all three dimensions. The final project for the class required teachers to submit the following: a task that they developed, goals for the task, potential solutions/student responses, and teachers' reasoning about how the task utilized technology as a reorganizer.

*Analysis*

Each author independently evaluated the 23 tasks submitted by teachers along each dimension of the IGS Framework, and discussed their coding of the tasks to come to a consensus on the use of IGS for each task. In addition, each task was coded with regard to potential cognitive demand using the Instructional Quality Assessment (IQA) Mathematics Toolkit (Matsumura, Garnier, Slater, & Boston 2008; Boston, 2012). Two of the authors and an outside IQA expert independently scored the tasks for potential level of cognitive demand, and agreed on 21 of the 23 tasks (discrepancies were resolved for the other two). Finally, patterns related to technology use as an amplifier/reorganizer and potential level of cognitive demand were examined.

## Results

Table 1 below depicts how the 23 tasks were evaluated with regard to the use of IGS and in terms of cognitive demand. A task appearing in the Amplifier column means that it used IGS as an amplifier along each dimension of the IGS framework, whereas a task that used IGS a reorganizer along any of the three dimensions appears in the Reorganizer column, as we were interested in knowing if teachers could use IGS to pursue a particular goal as represented by a dimension of the framework

Table 1. Teachers' Use of IGS & Cognitive Demand

| | **Amplifier** | **Reorganizer** | Total |
|---|---|---|---|
| **High** | 5 | 17 | 22 |
| **Low** | 1 | 0 | 1 |
| Total | 6 | 17 | 23 |

Note that all but one task was considered to be high level, and 17 of the 23 tasks used IGS as a reorganizer along at least one of the dimensions of the IGS Framework. With regard to the research questions, this suggests that most teachers were able to successfully develop a task that uses IGS as a reorganizer, and in the process create a task with high cognitive demand. Furthermore, it is important to note every task that used IGS as a reorganizer along one of the dimensions of the framework was also a high level task.

The IGS Framework was developed with a middle and secondary focus, so a question raised during analysis was how answers to the research questions might differ according to whether a teacher was middle/secondary or elementary. Tables 2 and 3 depict the results broken down accordingly.

Table 2. Tasks created by middle/secondary teachers.

| | **Amplifier** | **Reorganizer** | Total |
|---|---|---|---|
| **High** | 1 | 6 | 7 |
| **Low** | 1 | 0 | 1 |
| Total | 2 | 6 | 8 |

Table 3. Tasks created by elementary teachers.

| | **Amplifier** | **Reorganizer** | Total |
|---|---|---|---|
| **High** | 4 | 11 | 15 |
| **Low** | 0 | 0 | 0 |
| Total | 4 | 11 | 15 |

When designing a task using IGS as a reorganizer, the results suggest there is little difference between elementary or secondary teachers, as 73% of the former and 75% of the latter were successful in this regard.

## Discussion

The results suggest the IGS Framework, and teacher education activities designed to help teachers use it to design a task that uses IGS as a reorganizer, were relatively successful. In addition, it appears elementary teachers are equally capable of learning to use it as their middle/secondary counterparts. This result is encouraging, but the practical value of this learning was still in question. Does learning to use the IGS Framework translate into better mathematics instruction? The fact that every teacher but one created a high level task demonstrates that using the IGS Framework can support teachers' practice in a way that has proven implications for student learning.

These results also confirm previous results by the first two authors. Sherman (2014) found that the use of technology as a reorganizer by students during implementation was related to high cognitive demand. Results of the present study demonstrate the same finding for tasks *as written*. This is evident in the fact that no tasks using technology as a reorganizer were categorized as low-level. Cayton (2012) found the use of Sinclair's Design Principles (2003) was related to cognitively demanding tasks. Given that the amplifier/reorganizer distinction and Sinclair's Design Principles form the theoretical basis for the IGS Framework, the results of the present study further validate the relationship between use of the IGS Framework and high-level tasks.

Providing students with opportunities to engage in high level mathematical thinking is an important element of high quality mathematics instruction, and research has shown this is difficult task for teachers (Stein, Grover, & Henningsen, 1996), and no less so when incorporating technology into a mathematics lesson (Sherman, 2014; Cayton, 2012). As written tasks set the ceiling for everything else that happens in a lesson, it is important that teachers learn to identify and select high-level tasks for their students. Given widespread availability of IGS, and its potential to support student learning, it is also important that teachers learn how to use it support students' thinking. Results of the present study suggest that teachers can learn to use the IGS Framework to develop these skills. Thus, it is important that such opportunities be incorporated into teacher education in both courses and professional development.

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