Learning to Graph: A Comparison Study of Using Probe or Draw Tools in a Web-Based Learning Environment

Libby F. Gerard, Amber Zertuche, & Marcia C. Linn, UC Berkeley, 4407 Tolman Hall, Berkeley, CA 94720
Email: libby.gerard@gmail.com, anzertuche@gmail.com, mclinn@berkeley.edu

Abstract: Research suggests that motion probes can significantly enhance student understanding of position/time graphs. New, online drawing tools offer opportunities to augment or even replace motion probes—especially in classrooms that allow little space for 35 students to move. We compare how 8th grade students (N=315) learned to construct, interpret and critique graphs using motion probes or drawing tools. Post-unit individual and student-pair outcome measures indicate probes and drawing activities both significantly improve student science learning. Embedded assessments illustrate unique affordances of the precision allowed with drawing tools and the immediate feedback provided by probes in online units.

Rationale
Graphing is a critical concept in the development of mathematical and scientific thinking (Leinhardt, Zaslavsky & Stein, 1990), and a key practice used in personal and policy decisions during life (National Research Council, 2010). Linking graphs to other symbolic systems in order to interpret and communicate evidence is challenging for students to learn. For instance, those who can solve graphing problems in mathematics are often unable to access this knowledge in science. Students often interpret graphs as pictures (Leinhardt et al, 1990).

Previous research suggests advantages of using motion probes to support student learning about graphing (e.g. Zucker, Tinker, Staadt, Mansfield, Metcalf, 2008; Sokoloff, Laws & Thornton, 2007). New drawing tools can augment or even replace motion probes for schools with large class sizes. Prior work illustrates the potential of drawing tools to help students make connections between multiple representations of scientific concepts (Zhang & Linn, 2011). We examine the relative benefits of probes and drawing tools to support student learning about graphing in the Web-based Inquiry Science Environment (WISE, http://wise.berkeley.edu, Linn & Eylon, 2011).

Methodology
Curriculum, Study Design, Participants, Data Sources, and Scoring
This study compares an activity using motion probes to a similar activity using drawing tools embedded in a WISE inquiry unit called Graphing Stories. The unit and assessments were designed to support knowledge integration learning processes (Linn & Eylon, 2011). The probes connect seamlessly to the WISE environment, allowing students to collect, interpret, and utilize the probe data within WISE Students took approximately five 50-minute class periods to complete Graphing Stories, spending approximately two of the class periods on the probe/draw activities (see Table 1). The probe/draw activities guided students to interpret, construct and critique graphs of increasingly complex verbal descriptions of motion. Two 8th grade teachers and their 315 students participated in this study in an urban-fringe, moderately diverse (30% non-white), affluent (6% reduced lunch), California school district.

Students completed 2 embedded assessment items in pairs immediately after the probe/draw activities and 2 pre/post assessments individually before and after the unit. We scored these assessments using 5-point knowledge integration rubrics to capture students’ increasingly integrated understanding of direction, start and end points, distances and rate in graph construction and interpretation (Liu, Lee, Hofstetter, & Linn, 2008). In addition, we utilized WISE log data, classroom video, field notes, and end-of-unit teacher interviews to generate case studies of students in each condition. The WISE log data documented each version of student drawings, critique, and explanations in the probe/draw activities. The video captured eight student pairs, four using probes and four using draw tools.

Results
Students in both the probe and draw groups made significant pre/post gains in their understanding of position-time graphs (p<.001). There were no significant differences between the draw and probe groups on either the pretest or the posttest.

Students in the draw group constructed more precise graphs and verbal interpretations on the embedded assessments than students in the probe condition (7.46 versus 6.5 out of 10 total points). These students’ graphs and verbal descriptions were more likely to accurately represent direction, start and end points, distances, and rate. Students in the probe condition alternatively tended to construct graphs and interpretations that represented the correct direction but included only roughly similar start and end points, distances, and rates. This suggests
that the draw tools encouraged students to attend to the point-by-point details of graphs (local interpretation) while the probe condition encouraged students to attend to the graphs’ general shape or intervals of increase or decrease (global interpretation) (Leinhardt et al, 1990).

Students in the draw condition generated more non-normative ideas consistent with pictorial interpretations of graphs than students in the probe condition (McDermott et al, 1987). A substantial minority (28%) of student responses in the draw condition interpreted the graphs as a picture, describing the peaks as “up and down a hill” or as velocity graphs, “going fast then slow”. The probe condition on the other hand elicited significantly fewer such non-normative ideas (11% of student responses). This finding suggests that the probes more effectively helped students to distinguish graphs as representations of motion rather than as literal pictures, relative to the drawing tools. Our video observations show that the immediate feedback from the probe enabled students to see that their pictorial interpretations did not result in their expected graph support this conclusion.

The field notes and video suggest greater engagement by students using probes. Students who used the probes negotiated with their partner about how far to walk, how long, and how fast, while, students using the draw tools engaged in minimal if any peer discussion, choosing instead simply to alternate their attention between the verbal description of motion and graph construction. Both teachers reported that probes were more engaging to students, and according to one teacher gave the students and teachers, the feeling of “doing real science.” Students in the probe group struggled at times to focus on the relationship between their movement and the graphical representation, attending instead to data collection logistics and interference from others.

Table 1. Student Generated Walking Instructions and Corresponding Graphs

<table>
<thead>
<tr>
<th>Student-Generated Instructions for Graph C*</th>
<th>Corresponding Graph Generated Using Draw Tools</th>
</tr>
</thead>
<tbody>
<tr>
<td>at 0.5 meters, walk forward briskly for 2 seconds and you will reach 2 meters. then for 3 seconds slowly walk forward for .25 meters. Now turn around and walk back at a normal pace for another 5 seconds and 2 meters. now just stand still for 2 seconds.</td>
<td>![Graph C* Using Draw Tools]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Student-Generated Instructions for Graph C*</th>
<th>Corresponding Graph Generated Using Probe Tools</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start half a meter away from the motion sensor, walk 1.5 meter quickly in 2 seconds. Then slowly walk .25 of a meter in 3 seconds. Then walk 2 meters back towards the starting point in 5 seconds. Then stand still for 2 seconds.</td>
<td>![Graph C* Using Probe Tools]</td>
</tr>
</tbody>
</table>

**Discussion**

Although drawing provides a viable alternative to using motion probes to learn about position/time graphs there are tradeoffs. Combining these approaches could strengthen outcomes from units on motion. The opportunity, to “do real science” remains a unique advantage of probes. Future research will explore combining these activities.

**References**


**Acknowledgments**

We acknowledge the support of National Science Foundation Grants DRL-0918743, DRL-1119670, and DRL-0822388 in conducting this research. Views are those of the authors and not necessarily the views of the NSF.