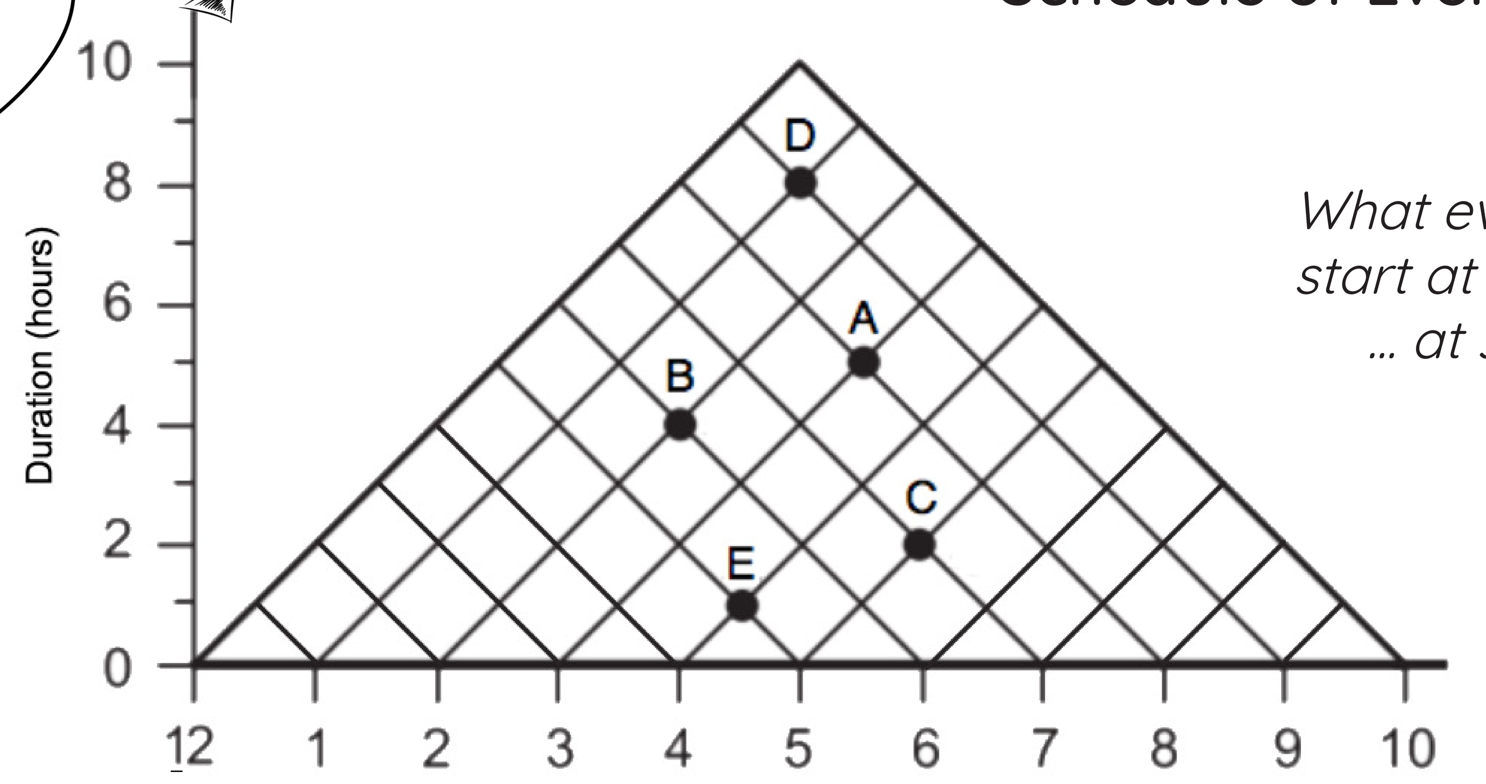
How can we scaffold comprehension for unconventional graphs?

Previous work on scaffolding graph comprehension has focused on connecting the features of a graph to its domain content (Mautone & Mayer, 2007). But what happens when we encounter a graph that is completely unfamiliar? The two graphs below represent the same information about a schedule of events. They are informationally equivalent: all data (start, end and duration) that can be read from one graph can be read from the other. But the graph on the left uses an unconventional coordinate system where a single point has two intersections with the x-axis —neither of which are orthogonal, as we expect in a Cartesian coordinate system. The Triangular Model of Interval Relations was introduced by a team of GIS researchers (Qiang, Vaicke, De Maeuer, Van de Weghe, 2014) looking for a more efficient way to represent large data sets of intervals. It is an alternative to the conventional representation for intervals in this domain —the linear model.

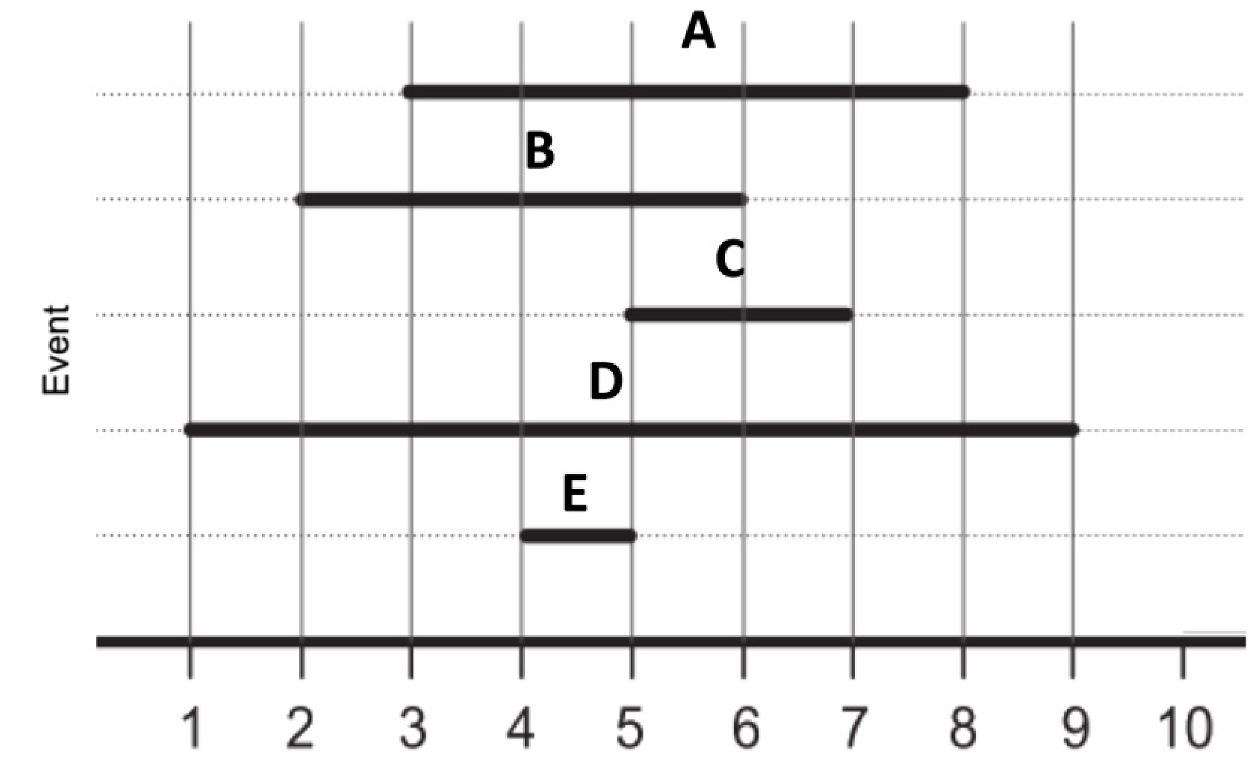
Can you read the graph?

Schedule of Events (A through E)



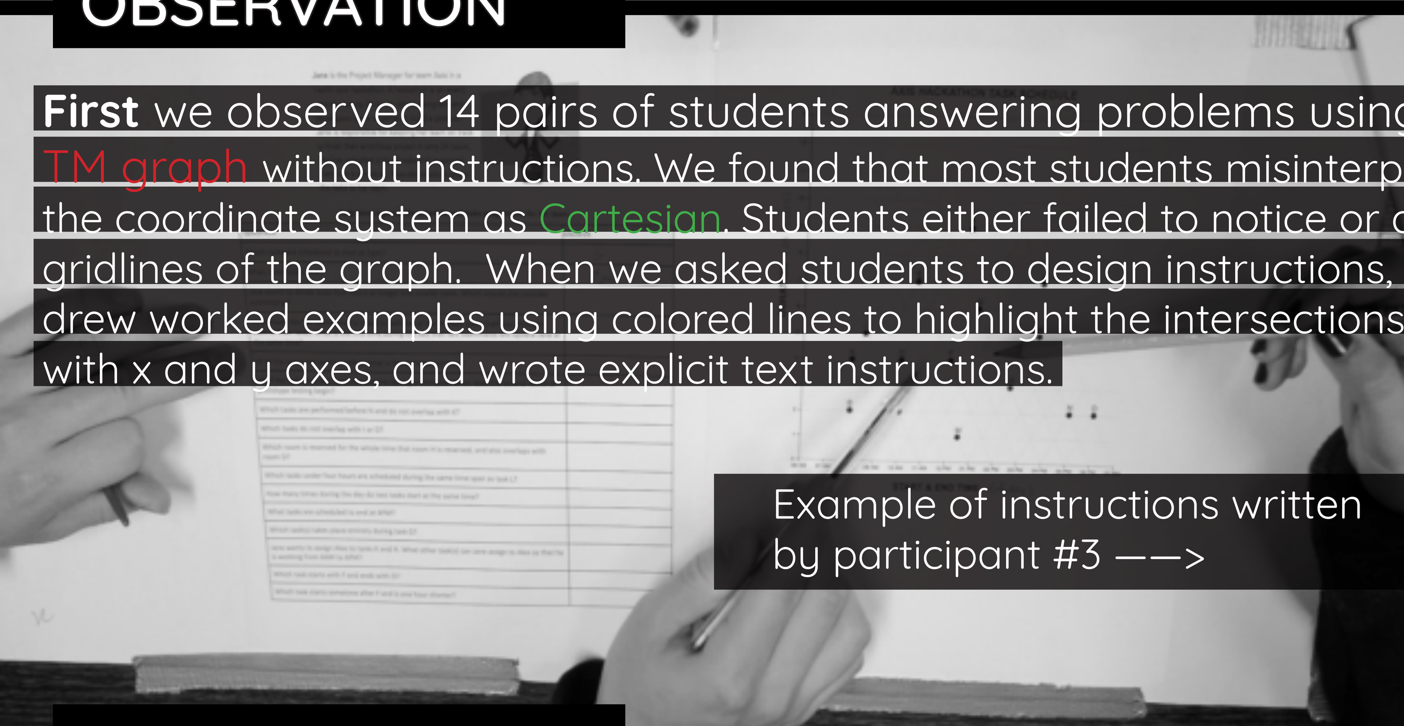
triangular model (TM)

What events start at 4pm? ... at 3pm?



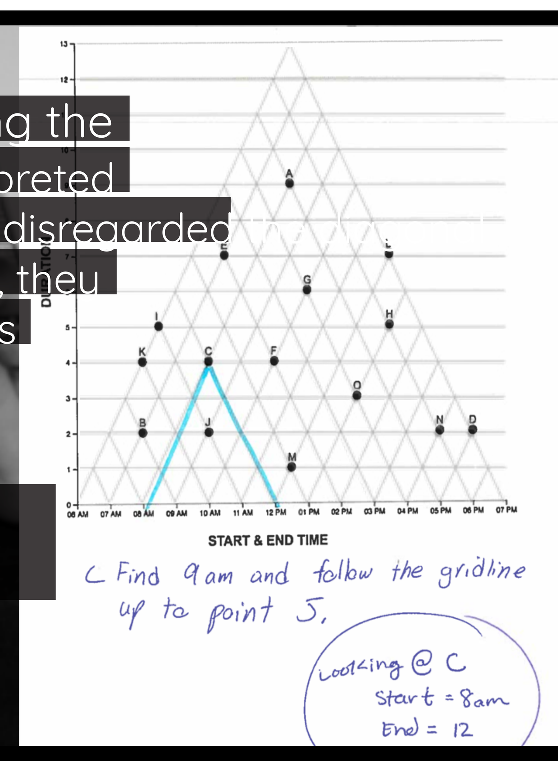
linear model (LM)

OBSERVATION



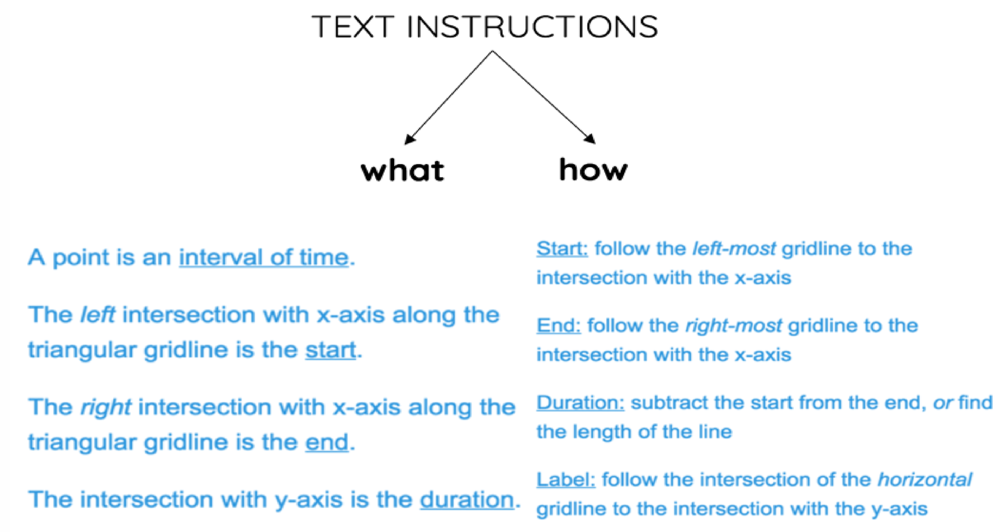
First we observed 14 pairs of students answering problems using the TM graph without instructions. We found that most students misinterpreted the coordinate system as Cartesian. Students either failed to notice or disregarded gridlines of the graph. When we asked students to design instructions, they drew worked examples using colored lines to highlight the intersections with x and y axes, and wrote explicit text instructions.

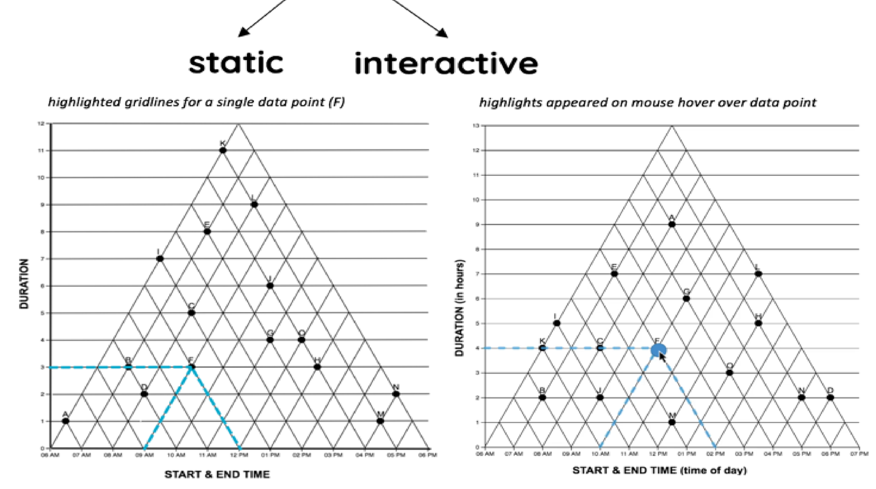
Example of instructions written by participant #3 ——>



DESIGN

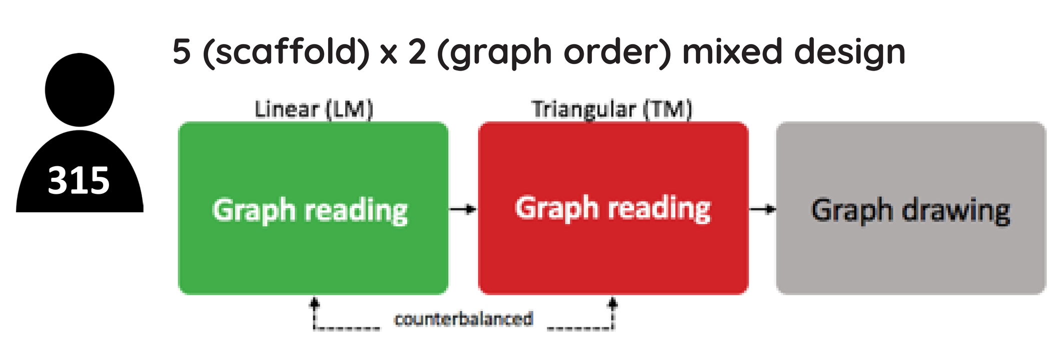
From these observations, we designed four scaffolds for the Trigular Model (TM) graph.





EXPERIMENT

Next we set out to test which of the scaffolds were most effective. 315 subjects completed three tasks in a computer lab, and were randomly assigned to one of the four scaffolds or a no-scaffold control group. First, each subject completed a graph reading task (15 questions) with each graph. Then, subjects were asked to draw a Triangular Model graph for a small data set. Accuracy (# problems correct) and response time were measured for each task.



Materials. The 15 questions in each graph reading task asked about relation between intervals of time (e.g. "What events start before 9 am? What events were after B, but end before 7pm?" The scaffold was turned on for the first 5 questions. Questions in each graph task were matched for content and difficulty

HYPOTHESES

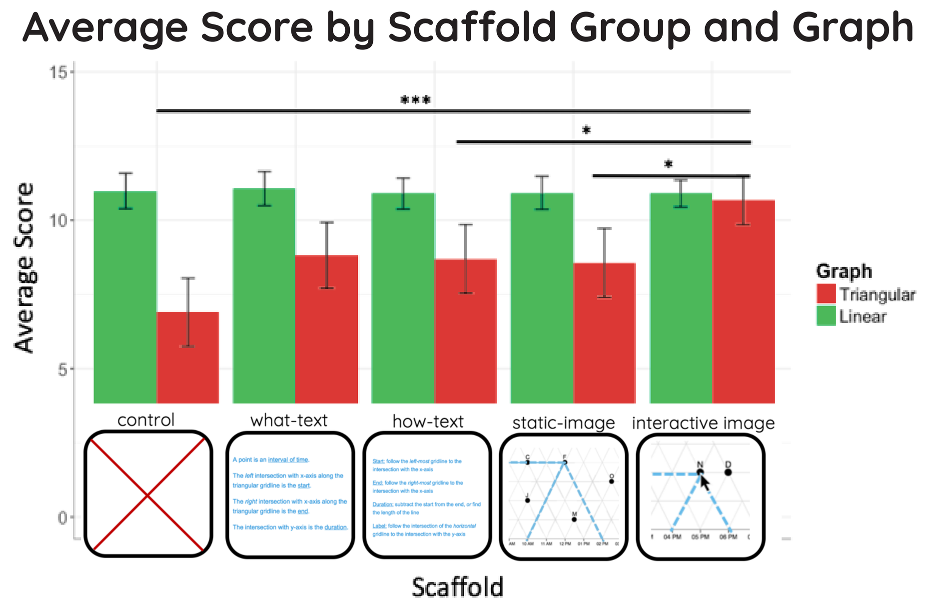
Scaffolds will not effect performance on the Linear Model graph
The LM graph is so conventional, it does not need scaffolding

Scaffolds will improve performance on the Triangular Model graph
Each of the scaffolds groups will outperform the no-scaffold control

Graph order will act as a scaffold
Students who see the linear graph before the triangular graph will be less likely to misinterpret the triangular coordinate system.

EFFECT OF SCAFFOLD

Average Score by Scaffold Group and Graph



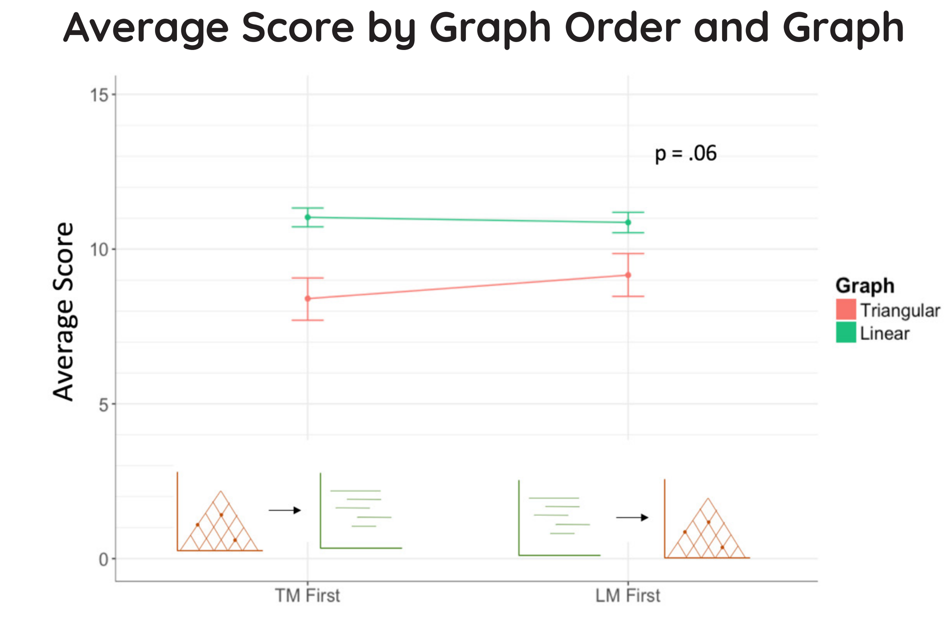
✓ **Scaffolds did not effect performance on the Linear Model graph**
No significant differences between scaffold groups on LM task

!! **Only interactive image was effective for most subjects on TM graph**
Scores for the text and static image scaffold conditions were not significantly different than the no-scaffold control.

✓ **Order was marginally effective as a TM graph scaffold**
Students performed better when they saw the LM graph *first*, likely because attention was drawn to the differences between the graphs

EFFECT OF ORDER

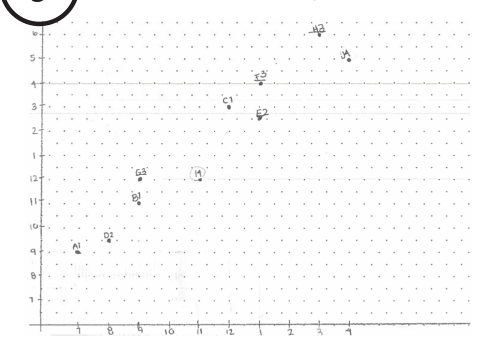
Average Score by Graph Order and Graph



DRAWING THE TM GRAPH

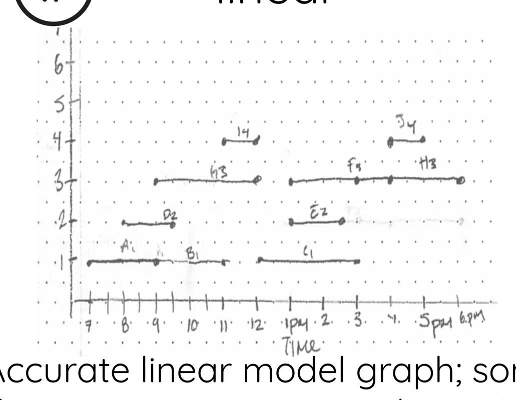
We categorized the drawings produced by the students into five groups

3 "scatterplot"



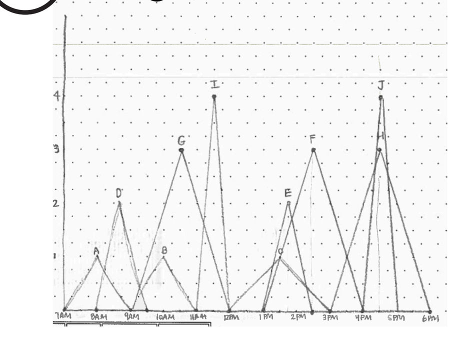
Plot start and end time on the x & y axes; duration not represented

17 "linear"



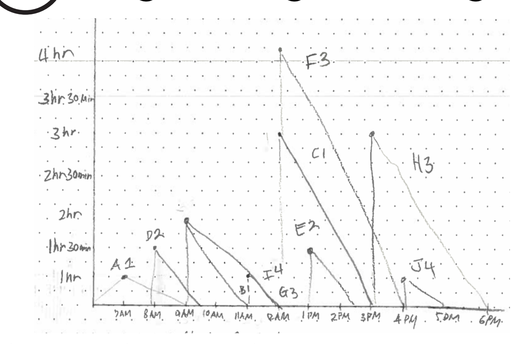
Accurate linear model graph; some drew duration on y axis (overplotting), others drew label on y axis

22 "asymmetric triangular"



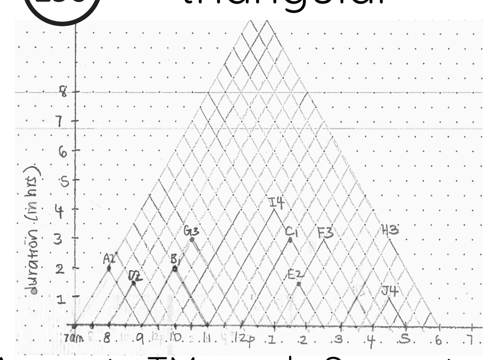
Plot label on y axis (rather than duration) results in non-similiar triangles. These students tended to have high TM scores.

44 "right-angle triangular"



Plots orthogonal intersection with x axis for start (or end) time, resulting in right angle triangles. Tended tend have low TM scores.

230 "triangular"



Accurate TM graph. Some students drew all gridlines, others drew only gridlines for each data point.

CONCLUSIONS

Convention is hard to overcome

The unconventional TM graph is challenging to interpret. Without guidance, most students misinterpret the coordinate system as Cartesian. Only an interactive image scaffold was effective for most participants. Even with explicit directions, many students do not realize they are misreading the graph.

REFERENCES

Mautone, P. D., & Mayer, R. E. (2007). Cognitive aids for guiding graph comprehension. Journal of Educational Psychology, 99(3), 640–652.

Qiang, Y., Valcke, M., De Maeyer, P., & Van de Weghe, N. (2014). Representing time intervals in a two-dimensional space: An empirical study. Journal of Visual Languages and Computing, 25(4), 466–480.

Amy Rae Fox, MA & James Hollan, PhD amyraefox@gmail.com www.alwaybeenamy.com

UC San Diego Cognitive Science