For Good Measure: Identifying Student Measurement Estimation Strategies Through Actions, Language, and Gesture

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Abstract: Measurement informs our actions and decisions well beyond school, necessitating that students develop a conceptual understanding of measurement alongside the procedural ability to measure objects. We present a first attempt to explore how students express their understanding of measurement by analyzing the behavior of college and elementary students as they completed measurement estimation tasks. We clustered observable student behavior to identify six profiles of behavioral strategies which may indicate different levels of conceptual understanding.

Keywords: measurement estimation, gesture, action, speech, cluster analysis

Introduction

Since measurement skills and concepts are used on a daily basis, it is crucial for elementary curricula to focus on helping students develop an understanding of measurement concepts as well as building strategies for application beyond procedural, physical measurement. However, measurement is poorly learned in classrooms across the world (Zacharos, 2006). Some research has shown successful measurement estimation strategies, such as using a reference-point strategy (Joram et al., 2005), however, more work needs to be done to identify successful strategies that could be beneficial to incorporate in elementary school instruction and what kinds of student behaviors may indicate different levels of conceptual understanding and shortcomings along the way.

To do so, this project explores the measurement estimation strategies exhibited by experienced college-age learners as well as those displayed by inexperienced elementary-aged learners by looking at their actions during measurement estimation tasks to explore how experienced and novice measurers approach measurement estimation tasks and express their understanding. We use both populations to identify successful strategies that indicate a high level of conceptual understanding as well as behavioral strategies that may indicate lower levels of understanding.

Methods

This project uses video data from 51 participants (n=29 college students; n=22 elementary students) as they completed eight measurement estimation tasks, without accuracy feedback, in a one-on-one interview. During the study, participants were asked to estimate the dimensions of geometric objects such as prisms, spheres, and cylinders of various sizes (e.g., participants were presented with a 24” cylinder and asked to estimate its height). After verbally providing an answer for each task, participants were asked to explain their answer. A total of 394 tasks (229 college, 165 elementary) were completed, video recorded, coded, and then analyzed. Four coders met regularly to collaboratively code college participant videos and discuss points of controversy until they obtained 75% agreement (3 out of 4 coders) across 80% of items on seven given cases, then individually coded the remaining data.

The video data was analyzed using a coding guide designed to provide quantitative data about the behavior displayed by students as they completed each task and explained their strategies. This coding guide builds off previous work on gesture analysis (e.g., Alibali & Nathan, 2012), with the intent to capture behaviors such as gesture type, action/speech/gesture congruence, and the mathematical accuracy of speech. The 35 total items include binary markers of present behaviors (e.g., whether the participant *used a dowel* while measuring) and categorical items depicting overall measurement *strategies*. For this project, all items were transformed into binary features.

From the behavioral items coded, 44 features were used for analysis to describe each aspect of each student’s behavior during each of the measurement estimation tasks. Students’ estimation errors were calculated and used as a dependent measure. We applied *k*-means clustering using Jaccard distance to identify the emerging groups, as all features are binomial. The representative features distinguishing samples (tasks) found within each cluster were then used to interpret each group then observe the distribution of students (in regard to age) found within each cluster.

Table 1: Cluster labels, behavior, and distribution of students per cluster

Cluster Label	Behaviors	N	% of College Students	% of Elementary Students	Chi-Square p-value
Low Effort	Eyeballing, no double-checking of answers, no dowel use or end-point marker	43	8.7%	13.9%	0.102
Confused	No gestures, long answer time, unknown verbal strategies	31	6.1%	10.3%	0.127
High Performance & Conceptual Understanding	Proportional action and verbal strategy, correct math reasoning, precise language	82	32.8%	4.2%	<0.001
High Effort, Low Performance	Varied long and short answer times, action-gesture-speech mismatch, many gestures	51	6.6%	21.8%	<0.001
Counters	Used counting verbal strategy, short answer time, imprecise language	63	3.9%	32.7%	<0.001
High Effort & Experience	Long answer time, correct reasoning, double-checked answers, estimation verbal strategy	124	41.9%	17%	<0.001

Results and Discussion

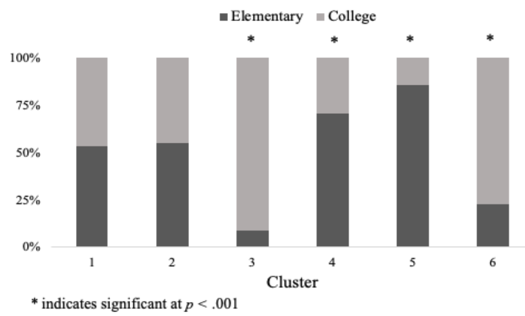

Table 1 shows the six clusters; the proportion of each age group and statistically reliable differences are in Figure 1.

Next, we compared student performance by cluster and task. In both tasks, rather unsurprisingly, elementary students consistently exhibited higher estimation error than college students, though this was not always statistically significant. Significant differences in performance were found only in the case of Clusters 2 and 4. Few elementary students exist in Cluster 3, which denotes high conceptual understanding through action, verbal, and gesturing strategies. This suggests that the elementary students observed were generally lacking the ability to demonstrate or articulate a strong understanding.

The differences in exhibited action, verbal, and gesture strategies across behavior profiles highlight some of the differences in conceptual understanding that appear between age groups. Particularly, the behaviors represented in Clusters 3 and 6 include proportional action and verbal strategies, and correct mathematical reasoning. Elementary students, conversely, were more likely to demonstrate a strategy based on the use of counting in increments of varying correctness to arrive at an estimate (Cluster 5). These students were also more likely to demonstrate an incongruence between their actions while estimating and their speech and gestures while explaining their answer (Cluster 4). These incongruences are consistent with prior work on leaners' speech-gesture mismatch (Alibali & Goldin-Meadow, 1993).

Interestingly, the profiles are not exclusively college or elementary students as indicated by the first profile which shows low effort among both college and elementary students. Additionally, the second profile of behaviors indicates confusion, demonstrated by both groups of students. It is also worth highlighting that there is relatively low variance in the performance of both groups across clusters. This finding suggests that there are distinctive differences between a student's ability to estimate and that student's ability to articulate the applied strategies.

References

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Acknowledgments

This material is based upon work supported by the National Science Foundation Graduate Research Fellowship Program and Grant #1652579. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.