Developing a Reasoning Inventory for Measuring Physics Quantitative Literacy

Trevor I. Smith
Rowan University

Suzanne White Brahmia
University of Washington

Alexis Olsho
University of Washington

Andrew Boudreaux
Western Washington University

In an effort to improve the quality of citizen engagement in workplace, politics, and other domains in which quantitative reasoning plays an important role, Quantitative Literacy (QL) has become the focus of considerable research and development efforts in mathematics education. QL is characterized by sophisticated reasoning with elementary mathematics. In this project, we extend the notions of QL to include the physics domain and call it Physics Quantitative Literacy (PQL). We report on early stage development from a collaboration that focuses on reasoning inventory design and data analysis methodology for measuring the development of PQL across the introductory physics sequence. We have piloted a prototype assessment designed to measure students' PQL in introductory physics: Physics Inventory of Quantitative Literacy (PIQL). This prototype PIQL focuses on two components of PQL: proportional reasoning, and reasoning with signed quantities. We present preliminary results from approximately 1,000 undergraduate and 20 graduate students.

Keywords: Quantitative Literacy, Physics, Assessment, Psychometrics

The development of students' PQL is an important goal in many introductory physics courses, but previous research suggests that students often do not achieve robust learning gains (Brahmia, 2017). We aim to develop a valid and reliable reasoning inventory to measure students' PQL. We present preliminary results from an 18-item reasoning inventory focusing on two constructs as proxies for PQL in general: reasoning using ratios and proportions (Arons, 1983; Boudreax et al., 2015), and about signed quantities (Brahmia & Boudreaux, 2016; Brahmia & Boudreaux, 2017; Bajracharya et al., 2012; Hayes & Wittmann, 2010; Vlassis, 2004). Future iterations will include items involving co-variational reasoning (Carlson et al., 2010).

Data for our primary analyses are comprised of responses from 1,076 undergraduate introductory physics students. We use descriptive statistics and classical test theory (CTT) to analyze our results. Overall, scores are fairly normally distributed (small but negative values of both skewness and kurtosis, -0.3 and -0.2, respectively) with an average (mean, median, and mode) of 11 out of 18 correct, and a standard deviation of 3.0. The internal reliability is below the commonly accepted threshold for making measurements of individuals: Cronbach's ⟨ = 0.67 < 0.80 (Doran, 1980). CTT results indicate that some questions may be too easy for our target population, with difficulty > 0.8. In addition, student performance on no single item strongly correlates with the overall score, i.e. CTT discrimination < 0.6 (Wiersma & Jurs, 1990). The test is a work in progress and will continue to be revised based on our analyses.

Results from graduate students show that one multiple-choice-multiple-response item about negative charge is particularly difficult: only 3/22 students answered completely correctly, compared to at least 18/22 for five other items. This highlights the interesting case of the sign of charge being used as a label for a type of charge, which is uncommon for scalar quantities.

Future work will involve interviewing students and faculty to validate the interpretations of inventory items (Adams & Wieman, 2010), as well as item development and refinement.

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