Energy transfer-transformation test development in science education

Lauri Kõlamets[1,*], Heili Kasuk[2], Jack Barrie Holbrook[3], Rachel Mamlok-Naaman[4]

[123]Tartu University, Tartu, Estonia;
[4]Weizmann Institute of Science, Rehovot, Israel
**lauri.kolamets@ut.ee*

Introduction. Energy is a key concept in everyday life. In science education energy is identified as a core idea, or a cross-cutting concept and researchers have propose to have four main components to characterise the concept of energy: energy source or form, energy transfer-transformation, energy dissipation, and energy conservation. Science educators have indicated that students' have problems understanding the concept of energy[1]. Researchers[2,3] indicate that the fragmentation of the concept of energy (EC) between science subjects leads to students incomplete conceptualisation of the energy as a whole. To determine student-attained EC curriculum outcomes non-direct psychometric measurements, based on items with underlying latent variables can be used. The latent variable is a constructed variable that comes prior to the items of which we measure and the level of attainment can be inferred through a mathematical model based on students' responses. For assissing students' cognitive processes using a content-based theoretical framework instrument needs to use items which are developed based on a learning taxonomy, furthermore, for determining students' cognitive processes, at least in three levels are required and it has suggesed that, besides determining content-dependent knowledge, time spent, and complexity of the task need to be included.

Methods. To develop a meaningful ET, this study undertook following steps: (i) To initiate the ET, an analysis of the Estonian 7-9th grade science curriculum 'energy` concept (energy transfer and transform) was undertaken[4], (ii) Based on previous results the 2019 Trends in International Mathematics and Science Study (TIMSS) cognitive complexity (knowing, applying, and reasoning) model[5] was added to the ET. (iii) The multiple-choice test items 'answer option character length' was approximately set to be equal, while based on a physical phenomenon model[6], a coding strategy was set for giving points per item answers: 4 points = physical phenomenon model (PPM) and mathematical model (MAM) correct; 3 points = PPM correct, MAM incorrect; 2 points = PPM incorrect, MAM correct; 1 point = PPM and MAM incorrect; 0 points = unanswered response). (iv) The test items were divided into 5 different constructs, 1-4 focusing on the 4 science subjects: biology, chemistry, earth science, physics, and based on the TIMSS 2019 science framework a 5th construct with a focus on research skills.

Analyses and Findings. Rasch analysis was undertaken using WINSTEPS. The results from Table 2 indicate a ET is fitting within the person reliability (.82) and person separation (2.12) parameters. Point-measure correlation value with value 0.41 indicates a need to increase item complexity in future development. The Rasch item distractor frequencies in measure suggest a change in the order between 3- and 2-point answers. Nevertheless, the ET Rasch results were seen as providing a good base for further e.g. checking if the proposed model latent variables were also supported by statistics.

Acknowledgements

This research is supported by a) European Union Horizon 2020 (L 347 - 2013-12-11) programme 'Addressing Attractiveness of Science Career Awareness' (ID: 952470), b) European Union Regional Development Fund through the Estonian Dora Plus Sub-Activity 1.1 Short-term mobility scholarship. c) ÕÜF12 'Extraction of rare earth metals from natural ores by ionic liquids.'

References

[1]Herrmann-Abell, C.F., & DeBoer, G.E. (2018). Investigating a learning progression for energy ideas from upper elementary through high school. *Journal of Research in Science Teaching*, *55*(1), 68-93. https://doi.org/10.1002/tea.21411

[2]Cooper, M. M., & Klymkowsky, M. W. (2013). The trouble with chemical energy: why understanding bond energies requires an interdisciplinary systems approach. *CBE—Life Sciences Education*, *12*(2), 306-312. https://doi.org/10.1187/cbe.12-10-0170

[3]Dreyfus, B. W., Redish, E. F., & Watkins, J. (2012). Student views of macroscopic and microscopic energy in physics and biology. In P. V. Engelhardt, C. Singh & N. S. Rebello (Eds.), *AIP Conference Proceedings* (Vol. 1413, No. 1, pp. 179-182). American Institute of Physics. https://doi.org/10.1063/1.3680024

[4]Kõlamets, L., Kasuk, H., Holbrook, J., & Mamlok-Naaman, R. (2023). The Relevance of Learning Outcomes Included in Estonian Grade 7-9 Science Subject Curricula Associated with the Concept of Energy. *Journal of Baltic Science Education*, *22*(4), 653-667.

[5]Mullis, I.V.S., Martin, M.O., Goh, S., & Cotter, K. (Eds.). (2016). *TIMSS 2015 encyclopedia: Education policy and curriculum in mathematics and science*. Retrieved from: http://timssandpirls.bc.edu/timss2015/encyclopedia/

[6]Greca, I. M., & Moreira, M. A. (2002). Mental, physical, and mathematical models in the teaching and learning of physics. Science education, 86(1), 106-121.