Physics expertise in light of cognitive and affective variables – Evidence from the PhysicsOlympiad

Peter Wulff[a], Stefan Petersen[b], Tim Höffler[b], and Knut Neumann[b]

[a]Physics Educational Research Group, University of Potsdam, Karl-Liebknecht-Straße 24/25, 14476 Potsdam-Golm
[b]Leibniz Institute for Science and Mathematics Education, Olshausenstrasse 62, 24118 Kiel, Germany

ARTICLE HISTORY
Compiled March 1, 2019

ABSTRACT
Given the need for high-achieving students to engage in science, technology, engineering, and math (STEM), this study seeks to characterize successful students in the Physics Olympiad as a means to enable future educational efforts to be more in congruence with the characteristics of the students. On the basis of the expectancy-value model of achievement motivation and research in expertise, $N = 141$ students were tracked in their engagement with the Physics Olympiad and administered appropriate motivational and cognitive constructs. The dependent outcome variable was the success the students had in their participation in the Physics Olympiad. Results indicate that successful students can be characterized through high skills in physics problem solving and positive motivational attributes, namely a high expectation to be successful in the Physics Olympiad. These results pave the path to more transparency for what comprises expertise in domains like physics such that designated educational efforts can motivate and foster more students.

KEYWORDS
Problem solving, Physics competitions

Acknowledgement(s)

Disclosure statement

We are not aware of potential conflicts of interest that relate to the results reported in this study.

CONTACT Peter Wulff. Email: peter.wulff@uni-potsdam.de

References

Aljughaiman, A. M., & Ayoub, A. E. A. (2012). The effect of an enrichment program on developing analytical, creative, and practical abilities of elementary gifted students. *Journal of Education for the Gifted*, *35*, 153–174.

Anderson, J. R. (1996). Act: A simple theory of complex cognition. *American Psychologist*, *51*(4), 355–365.

Bhaskar, R., & Simon, H. A. (1977). Problem solving in semantically rich domains: An example from engineering thermodynamics. *Cognitive Science*, *1*, 193–215.

Bortz, J., & Döring, N. (2002). *Forschungsmethoden und evaluation.* Berlin, Heidelberg: Springer Berlin Heidelberg.

Bransford, J., Brown, A. L., & Cocking, R. R. (2000). *How people learn.* Washington, D.C.: National Academies Press.

Bransford, J., Sherwood, R., Vye, N., & Rieser, J. (1986). Teaching thinking and problem solving: Research foundations. *American Psychologist*, *41*, 1078–1089.

Britner, S. L., & Pajares, F. (2006). Sources of science self-efficacy beliefs of middle school students. *Journal of Research in Science Teaching*, *43*(5), 485–499.

Docktor, J. L., Dornfeld, J., Frodermann, E., Heller, K., Hsu, L., Jackson, K. A., ... Yang, J. (2016). Assessing student written problem solutions: A problem-solving rubric with application to introductory physics. *Physical Review Physics Education Research*, *12*(1).

Eccles, J. S. (1983). Expectancies, values, and academic behaviors. In J. T. Spence (Ed.), *Achievement and achievement motives* (pp. 75–138). San Francisco, CA: Freeman and Company.

Eccles, J. S., & Wigfield, A. (1995). In the mind of the actor: The structure of adolescents achievement task values and expectancy-related beliefs. *Personality and Social Psychology Bulletin*, *21*(3), 215–225.

Feng, A. X., Campbell, J. R., & Verna, M. A. (2001). The talent development of american physics olympians. *Gifted and Talented International*, *16*(2), 108–114.

Field, A., & Miles, J. (2012). *Discovering statistics using r.* SAGE Publications.

Fortus, D. (2009). The importance of learning to make assumptions. *Science Education*, *93*(1), 86–108.

Friedman, T. L. (2005). *The world is flat.* New York: Farrar, Straus, & Giroux.

Funke, J., & Frensch, P. A. (2007). Complex problem solving. In D. H. Jonassen (Ed.), *Learning to solve complex scientific problems* (pp. 25–47). New York: Erlbaum.

Gardner, H. (1993). *Frames of mind: The theory of multiple intelligences.* New York: Basic Books.

Glaser, R. (1992). Expert knowledge and processes of thinking. In D. F. Halpern (Ed.), *Enhancing thinking skills in the sciences and mathematics* (pp. 63–75). Hillsdale, NJ: Erlbaum.

Good, C., Rattan, A., & Dweck, C. S. (2012). Why do women opt out? sense of belonging and women's representation in mathematics. *Journal of Personality and Social Psychology*, *102*(4), 700–717.

Hammann, M., & Jördens, J. (2014). Offene aufgaben codieren. In D. Krüger, I. Parchmann, & H. Schecker (Eds.), *Methoden in der naturwissenschaftsdidaktischen forschung* (pp. 169–178). Berlin and Heidelberg: Springer Spektrum.

Larkin, J. H., McDermott, J., Simon, D. P., & Simon, H. A. (1980). Expert and novice performance in solving physics problems. *Science*, *208*, 1335–1342.

Larkin, J. H., & Simon, H. A. (1987). Why a diagmm is (sometimes) worth ten thousand words. *Cognitive Science*, *11*, 65–99.

Lengfelder, A., & Heller, K. A. (2002). German olympiad studies: Findings from a retrospective evaluation and from in-depth interviews. where have all the gifted females gone? *Journal of Research in Education*, *12*(1), 86–92.

Leonard, W. J., Dufresne, R. J., & Mestre, J. P. (1996). Using qualitative problem–solving strategies to highlight the role of conceptual knowledge in solving problems. *American Journal of Physics*, *64*(12), 1495–1503.

Lubinski, D. (2010). Spatial ability and stem: A sleeping giant for talent identification and development. *Personality and Individual Differences*, *49*(4), 344–351.

Maloney, D. P. (2011). An overview of physics education research on problem solving: Getting started in physics education research.

Marsh, H. W., Chessor, D., Craven, R., & Roche, L. (1995). The effects of gifted and talented programs on academic self-concept: The big fish strikes again. *American Educational Research Journal*, *32*(2), 285–319.

Mason, A., & Singh, C. (2010). Helping students learn effective problem solving strategies by reflecting with peers. *American Journal of Physics*, *78*(7), 748–754.

McClelland, D. C. (1973). Testing for competence rather than for "intelligence.". *American Psychologist*, *28*(1), 1–14.

Oswald, F., Hanisch, G., & Hager, G. (2004). *Wettbewerbe und "olympiaden": Impulse zur (selbst)-identifikation von begabungen* (1. Aufl. ed.). Lit.

PCAST. (2012). *Engage to excel: Producing one million additional college graduates with degrees in science, technology, engineering, and mathematics: President's council of advisors on science and technology.*

Perels, F., Gürtler, T., & Schmitz, B. (2005). Training of self-regulatory and problem-solving competence. *Learning and Instruction*, *15*(2), 123–139.

Petersen, S., & Wulff, P. (2017). The german physics olympiad—identifying and inspiring talents. *European Journal of Physics*, *38*(3), 034005.

Pinker, S. (2018). Counter-enlightenment convictions are 'surprisingly resilient'. *Quillette*.

Reif, F., & Allen, S. (1992). Cognition for interpreting scientific concepts: A study of acceleration. *Cognition and Instruction*, *9*(1), 1–44.

Rosling, H., & Rosling Rönnlund, A. (2018). *Factfulness: Ten reasons we're wrong about the world and why things are better than you think.* London: Sceptre.

Shea, D. L., Lubinski, D., & Benbow, C. P. (2001). Importance of assessing spatial ability in intellectually talented young adolescents: A 20-year longitudinal study. *Journal of Educational Psychology*, *93*, 604–614.

Simon, H. A. (1980). Problem solving and education. In D. T. Tuma & R. Reif (Eds.), *Problem solving and education* (pp. 81–96). Hillsdale, NJ: Erlbaum.

Simon, H. A. (1983). *Reason in human affairs.* Stanford, CA: Stanford University Press.

Snow, R. E., Corno, L., & Jackson, D. N. (1997). Individual differences in affective and conative functions. In D. C. Berliner & R. C. Calfee (Eds.), *Handbook of educational psychology* (pp. 243–310). New York: Simon and Schuster and Macmillan.

Subotnik, R. F., Duschl, R., & Selmon, E. H. (1993). Retention and attrition of science talent: A longitudinal study of westinghouse science talent search winners. *International Journal of Science Education*, *15*(1).

Urhahne, D., Ho, L. H., Parchmann, I., & Nick, S. (2012). Attempting to predict success in the qualifying round of the international chemistry olympiad. *High Ability Studies*, *23*(2), 167–182.

Wai, J., Lubinski, D., & Benbow, C. P. (2009). Spatial ability for stem domains: Aligning over fifty years of cumulative psychological knowledge solidifies its importance. *Journal of Educational Psychology*, *101*, 817–835.

Wai, J., Lubinski, D., Benbow, C. P., & Steiger, J. H. (2010). Accomplishment in science, technology, engineering, and mathematics (stem) and its relation to stem educational dose: A 25-year longitudinal study. *Journal of Educational Psychology*, *102*(4), 860–871.

Wieman, C. E. (2007). Why not try a scientific approach to science education? *Change: The Magazine of Higher Learning*, *39*(5), 9–15.

1. Appendices