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The Problem with Teaching Science, Technology, Engineering, and Math as Inquiry Versus by Inquiry

Abstract

4-H professionals implementing problem-based learning and other minimally guided instruction techniques in science, technology, engineering, and math education often do so with learners working in small groups, a strategy that allows learners to construct knowledge through social interactions. However, educators who implement these techniques without an understanding of human cognitive architecture risk confusing the teaching of a discipline as inquiry with the teaching of the discipline by inquiry. The assumption that knowledge is learned best through experience does not account for the difference between experts who are practicing a profession and students who are learning to practice a profession.

Keywords: [STEM education](#), [experiential learning](#), [problem-based learning](#), [hands-on learning](#), [pedagogy](#)

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The Issue with Minimally Guided Instruction Techniques

Constructivist learning theory declares that people generate knowledge as they experience and interpret situations (Liu & Matthews, 2005). While he did not self-identify as a constructivist, Lev Vygotsky, a renowned learning theorist, shared in this notion that learners construct knowledge through experiencing their environment, believing that the environment also included social interactions (Davydov & Kerr, 1995). Extension and 4-H professionals who commonly implement constructivist theory through problem-based learning (PBL) and other minimally guided instruction techniques in science, technology, engineering, and math (STEM) education often do so with learners working in small groups, a strategy that may seem to make sense from a sociocultural perspective because it allows learners to construct knowledge through social interactions. However, Kirschner, Sweller, and Clark (2006) raised the point that without an informed understanding of human cognitive architecture, educators could mistakenly "confuse teaching of a discipline as inquiry (i.e., a curricular emphasis on the research processes within a science) with the teaching of the discipline by inquiry (i.e., using the research process of the discipline as a pedagogy or for learning)" (p. 78).

The Case for Strong Instructional Guidance

Schmidt, Volder, Grave, Moust, and Patel (1989) contended that the PBL process reinforces knowledge construction as students receive guidance in solving meaningful problems—maintaining that even with limited understanding, students still activate prior knowledge that in turn helps them prepare for learning. This is a primary reason that PBL is so often applied in 4-H STEM learning activities (Ota, DiCarlo, Burts, Laird, & Gioe, 2006). Also, Schwartz and Bransford's (1998) research from a controlled study of undergraduate students affirmed that those who solve problems in advance of lectures perform better on problem-solving tasks than students who only read the chapter or those who only solve problems with no lecture. Their finding indicates that attempting to solve a problem helps establish a readiness to learn from a lecture or other strongly guided instruction. Notwithstanding this perspective, Kirschner et al. (2006) made a strong case against minimal-guidance instructional techniques, such as PBL, contending that they are ineffective and inefficient means for altering long-term memory. The assumption that knowledge is learned best through experience is a misconception that accounts for no variance between experts who are practicing a profession and students who are fledgling. Drawing on the past half century of empirical research that "almost uniformly supports direct, strong instructional guidance rather than constructivist-based minimal guidance during the instruction of novice to intermediate learners" (p. 83), Kirschner et al. (2006) warn that "the epistemology of a discipline should not be confused with a pedagogy for teaching or learning it" and that "the practice of a profession is not the same as learning to practice the profession" (p. 83).

The Difference Between Practicing and Learning a Discipline

In clarifying the distinction between practicing a discipline and learning a discipline, Kirschner et al. (2006) paraphrased Kyle (1980) by explaining that expert performance, such as scientific inquiry, requires "unrestrained thinking capabilities after a person has acquired a broad, critical knowledge of the particular subject matter through formal teaching processes" (p. 79). Although Hmelo-Silver (2004) detailed evidence of reported effectiveness in applying PBL in medical schools and gifted education settings, she recognized that "there is less empirical evidence as to what students are learning and how" (p. 249), acknowledging that outside the context of undergraduate and professional learning environments there has been little research done with less mature learners.

Conclusion

The apparent weaknesses of PBL and other minimally guided instructional techniques signal the need for further research to be conducted around "developmentally appropriate ways . . . that varying kinds of scaffolding might be needed to help children learn while tackling complex problems" (Hmelo-Silver, 2004, pp. 252–253), especially in the context of 4-H youth development programming. Of course, PBL cannot simply be dismissed on the grounds of cognitive load theory (Paas, Renkl, & Sweller, 2003); the research thus far demonstrates a place for PBL in the education of less mature learners with appropriate levels of direct instruction and scaffolding because the technique supports active learning and situates learning in authentic problems. Indeed, Extension and 4-H professionals involved in the design and implementation of PBL and other minimally guided instruction techniques in the field of STEM education (e.g., robotics, computer science, engineering, rocketry) might argue that 4-H is an appropriate setting for PBL. Although this may be the case, these professionals have an obligation as educators to go beyond providing only authentic problems for youths to solve in the 4-H setting. They also need to carefully provide direct instruction and scaffolding because practicing STEM activities is not the same as learning STEM abilities; it is merely STEM theater.

References

- Davydov, V. V., & Kerr, S. T. (1995). The influence of L. S. Vygotsky on education theory, research, and practice. *Educational Researcher*, 24(3), 12–21.
- Hmelo-Silver, C. (2004). Problem-based learning: What and how do students learn? *Educational Psychology Review*, 16(3), 235–266.
- Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational Psychologist*, 41(2), 75–86.
- Kyle, W. C. (1980). The distinction between inquiry and scientific inquiry and why high school students should be cognizant of the distinction. *Journal of Research in Science Teaching*, 17(2), 123–130.
- Liu, C. H., & Matthews, R. (2005). Vygotsky's philosophy: Constructivism and its criticisms examined. *International Education Journal*, 6(3), 386–399.
- Ota, C., DiCarlo, C. F., Burts, D. C., Laird, R., & Gioe, C. (2006). Training and the needs of adult learners. *Journal of Extension*, 44(6), Article 6TOT5. Available at: <https://www.joe.org/joe/2006december/tt5.php>
- Paas, F., Renkl, A., & Sweller, J. (2003). Cognitive load theory and instructional design: Recent developments. *Educational Psychologist*, 38(1), 1–4.
- Schmidt, H. G., Volder, M. L. D., Grave, W. S. D., Moust, J. H. C., & Patel, V. (1989). Explanatory models in the processing of science text: The role of prior knowledge activation through small-group discussion. *Journal of Educational Psychology*, 81(4), 610–619.
- Schwartz, D. L., & Bransford, J. D. (1998). A time for telling. *Cognition and Instruction*, 16(4), 475–522.

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