REL Appalachia Ask A REL Response

Educator Effectiveness
December 2018

Question:

What are evidence-based strategies or approaches to science instruction for secondary students and how do they impact student outcomes?

Response:

Thank you for your request to our REL Reference Desk regarding evidence-based strategies and approaches to science instruction for secondary students. Ask A REL is a collaborative reference desk service provided by the 10 Regional Educational Laboratories (RELs) that, by design, functions much in the same way as a technical reference library. Ask A REL provides references, referrals, and brief responses in the form of citations in response to questions about available education research.

Following an established REL Appalachia research protocol, we searched for peer-reviewed articles and other research reports on evidence-based strategies and approaches to science instruction for secondary students. Based on recommendations from content experts, we specifically searched for evidence-based instructional practices, such as project-based learning, inquiry-based learning, and design-based learning. We focused on identifying resources that specifically addressed the effects of evidence-based strategies for science instruction on secondary student outcomes (for example, achievement and engagement). The sources included ERIC and other federally funded databases and organizations, research institutions, academic research databases, and general Internet search engines. For more details, please see the methods section at the end of this document.

The research team did not evaluate the quality of the resources provided in this response; we offer them only for your reference. Also, the search included the most commonly used research databases and search engines to produce the references presented here, but the references are not necessarily comprehensive, and other relevant references and resources may exist. References are listed in alphabetical order, not necessarily in order of relevance.

References

Furtak, E. M., Seidel, T., Iverson, H., & Briggs, D. C. (2012). Experimental and quasi-experimental studies of inquiry-based science teaching: A meta-analysis. *Review of Educational Research,* *82*(3), 300–329. Retrieved from http://getrealscience.org/wp-content/uploads/2012/12/Review-of-literature-on-Inquiry-based-science-teaching-20111.pdf

From the abstract: "Although previous meta-analyses have indicated a connection between inquiry-based teaching and improved student learning, the type of instruction characterized as inquiry based has varied greatly, and few have focused on the extent to which activities are led by the teacher or student. This meta-analysis introduces a framework for inquiry-based teaching that distinguishes between cognitive features of the activity and degree of guidance given to students. This framework is used to code 37 experimental and quasi-experimental studies published between 1996 and 2006, a decade during which inquiry was the main focus of science education reform. The overall mean effect size is .50. Studies that contrasted epistemic activities or the combination of procedural, epistemic, and social activities had the highest mean effect sizes. Furthermore, studies involving teacher-led activities had mean effect sizes about .40 larger than those with student-led conditions. The importance of establishing the validity of the treatment construct in meta-analyses is also discussed."

Halpern, D. F., Aronson, J., Reimer, N., Simpkins, S., Star, J. R., & Wentzel, K. (2007). *Encouraging Girls in Math and Science* (NCER 2007-2003). Washington, DC: National Center for Education Research, Institute of Education Sciences, U.S. Department of Education. Retrieved from https://eric.ed.gov/?id=ED498581

From the introduction: "This National Center for Education Research (NCER) Practice Guide is the second in a series of IES guides in education. The goal of this practice guide is to formulate specific and coherent evidence-based recommendations that educators can use to encourage girls in the fields of math and science. The target audience is teachers and other school personnel with direct contact with students, such as coaches, counselors, and principals. The practice guide includes specific recommendations for educators and the quality of evidence that supports these recommendations. This practice guide provides five recommendations for encouraging girls in math and science. These recommendations together form a coherent statement: To encourage girls in math and science, we need to begin first with their beliefs about their abilities in these areas, second with sparking and maintaining greater interest in these topics, and finally with building associated skills. The five recommendations are: (1) Teach students that academic abilities are expandable and improvable; (2) Provide prescriptive, informational feedback; (3) Expose girls and young women to female role models who have succeeded in math and science; (4) Create a classroom environment that sparks initial curiosity and fosters long-term interest in math and science; and (5) Provide spatial skills training."

Johnson, C. C., Zhang, D., & Kahle, J. B. (2012). Effective science instruction: Impact on high-stakes assessment performance. *RMLE Online: Research in Middle Level Education, 35*(9), 1–14. Retrieved from https://eric.ed.gov/?id=EJ974948

From the abstract: "This longitudinal prospective cohort study was conducted to determine the impact of effective science instruction on performance on high-stakes high school graduation assessments in science. This study provides powerful findings to support authentic science teaching to enhance long-term retention of learning and performance on state-mandated assessments. Students experienced some combination of zero to three effective teachers throughout their middle school experience. Findings revealed that all students who experienced effective science teachers who engaged students in inquiry-based science outperformed students who had less effective teachers. Additionally, those who had more effective teachers over time performed increasingly better. Implications for stakeholders will be discussed."

Mehalik, M. M., Doppelt, Y., & Schunn, C. D. (2008). Middle-school science through design-based learning versus scripted inquiry: Better overall science concept learning and equity gap reduction. *Journal of Engineering Education*, 97(1), 71–85. Retrieved from https://pdfs.semanticscholar.org/7388/43ada02aca59d6a1615f8e6198d4522340e5.pdf

From the abstract: "This paper contrasts performances overall and by gender, ethnicity, and socioeconomic status (SES) for middle school students learning science through traditional scripted inquiry versus a design-based, systems approach. Students designed and built electrical alarm systems to learn electricity concepts over a four-week period using authentic engineering design methods. The contrast study took place in the eighth grade of an urban, public school district, with the systems approach implemented in 26 science classes (10 teachers and 587 students) and the scripted inquiry approach implemented in inquiry groups of 20 science classes (five teachers and 466 students). The results suggest that a systems design approach for teaching science concepts has superior performance in terms of knowledge gain achievements in core science concepts, engagement, and retention when compared to a scripted inquiry approach. The systems design approach was most helpful to low-achieving African American students."

Osborne, J. F. (2010). Arguing to learn in science: The role of collaborative, critical discourse. *Science, 328*(5977), 463–466. Retrieved from https://pdfs.semanticscholar.org/d5c6/bc0b9ce69012cf1c0ff5d99ea7524ea6829f.pdf

From the abstract: "Argument and debate are common in science, yet they are virtually absent from science education. Recent research shows, however, that opportunities for students to engage in collaborative discourse and argumentation offer a means of enhancing student conceptual understanding and students' skills and capabilities with scientific reasoning. As one of the hallmarks of the scientist is critical, rational skepticism, the lack of opportunities to develop the ability to reason and argue scientifically would appear to be a significant weakness in contemporary educational practice. In short, knowing what is wrong matters as much as knowing what is right. This paper presents a summary of the main features of this body of research and discusses its implications for the teaching and learning of science."

Schroeder, C. M., Scott, T. P., Tolson, H., Huang, T.-Y., & Lee, Y.-H. (2007). A meta-analysis of national research: Effects of teaching strategies on student achievement in science in the United States. *Journal of Research in Science Teaching, 44*(10), 1436–1460. Abstract retrieved from https://eric.ed.gov/?id=EJ780840; full text available at https://onlinelibrary.wiley.com/doi/abs/10.1002/tea.20212

From the abstract: "This project consisted of a meta-analysis of U.S. research published from 1980 to 2004 on the effect of specific science teaching strategies on student achievement. The six phases of the project included study acquisition, study coding, determination of intercoder objectivity, establishing criteria for inclusion of studies, computation of effect sizes for statistical analysis, and conducting the analyses. Studies were required to have been carried out in the United States, been experimental or quasi-experimental, and must have included effect size or the statistics necessary to calculate effect size. Sixty-one studies met the criteria for inclusion in the meta-analysis. The following eight categories of teaching strategies were revealed during analysis of the studies (effect sizes in parentheses): Questioning Strategies (0.74); Manipulation Strategies (0.57); Enhanced Material Strategies (0.29); Assessment Strategies (0.51); Inquiry Strategies (0.65); Enhanced Context Strategies (1.48); Instructional Technology (IT) Strategies (0.48); and Collaborative Learning Strategies (0.95). All these effect sizes were judged to be significant. Regression analysis revealed that internal validity was influenced by Publication Type, Type of Study, and Test Type. External validity was not influenced by Publication Year, Grade Level, Test Content, or Treatment Categories. The major implication of this research is that we have generated empirical evidence supporting the effectiveness of alternative teaching strategies in science."

U.S. Department of Education, Institute of Education Sciences, What Works Clearinghouse. (2012). *Science intervention report: Chemistry That Applies*. Retrieved from https://eric.ed.gov/?id=ED529430

From the abstract: "'Chemistry That Applies' is an instructional unit designed to help students in grades 8–10 understand the law of conservation of matter. It consists of 24 lessons organized in four clusters. Working in groups, students explore four chemical reactions: burning, rusting, the decomposition of water, and the reaction of baking soda and vinegar. As part of the unit, students conduct experiments in which they cause these reactions to happen, obtain and record data in individual notebooks, analyze the data, and use evidence-based arguments to explain the data. The instructional unit engages the students in a structured sequence of hands-on laboratory investigations interwoven with other forms of instruction. Two studies reviewed by the What Works Clearinghouse (WWC) Science Topic Area investigated the effects of 'Chemistry That Applies' on middle school students. One study (Pyke, Lynch, Kuipers, Szesze, & Driver, 2004), summarized in this report, is a randomized controlled trial that meets WWC evidence standards. The remaining study does not meet WWC eligibility screens."

Wilson, C. D., Taylor, J. A., Kowalski, S. M., & Carlson, J. (2010). The relative effects and equity of inquiry-based and commonplace science teaching on students' knowledge, reasoning, and argumentation. *Journal of Research in Science Teaching, 47*(3), 276–301. Abstract retrieved from https://eric.ed.gov/?id=EJ881431; full text available at

https://www.wepickphysics.com/uploads/9/9/0/8/99088296/the_relative_effects_and_equity_of_inquiry-based_and_commonplace_science.pdf

From the abstract: "We conducted a laboratory-based randomized control study to examine the effectiveness of inquiry-based instruction. We also disaggregated the data by student demographic variables to examine if inquiry can provide equitable opportunities to learn. Fifty-eight students aged 14–16 years old were randomly assigned to one of two groups. Both groups of students were taught toward the same learning goals by the same teacher, with one group being taught from inquiry-based materials organized around the BSCS 5E Instructional Model, and the other from materials organized around commonplace teaching strategies as defined by national teacher survey data. Students in the inquiry-based group reached significantly higher levels of achievement than students experiencing commonplace instruction. This effect was consistent across a range of learning goals (knowledge, reasoning, and argumentation) and time frames (immediately following the instruction and 4 weeks later). The commonplace science instruction resulted in a detectable achievement gap by race, whereas the inquiry-based materials instruction did not. We discuss the implications of these findings for the body of evidence on the effectiveness of teaching science as inquiry; the role of instructional models and curriculum materials in science teaching; addressing achievement gaps; and the competing demands of reform and accountability."

Additional Ask A REL Responses to Consult

Ask A REL West at WestEd. (2013). *What does the research say regarding effectiveness of integrated models for science instruction in middle school*? Retrieved from https://relwest.wested.org/system/documents/pdfs/153/original/REL_West.website.integrated_model_in_science.May.2013.pdf?1397157104

Ask A REL Southeast at Florida State University. (2017). *What research has been conducted on connecting math and science instruction?* Retrieved from https://ies.ed.gov/ncee/edlabs/regions/southeast/aar/m_01-2017.asp

Ask A REL Southeast at Florida State University. (2017). *What research has been conducted on the efficacy of teaching single subject science in middle school compared to teaching integrated science courses?* Retrieved from https://ies.ed.gov/ncee/edlabs/regions/southeast/aar/u_02-2017_2.asp

Additional Organizations to Consult

National Math and Science Initiative: https://www.nms.org/

From the website: "Today, more than ever, a quality education is the foundation of opportunity. By 2020, almost two-thirds of all jobs will require post-secondary education or training. Nearly as many will require basic literacy in science, technology, engineering and math…NMSI works to expand access to challenging coursework and improve student achievement through proven programs that consistently produce measurable and lasting results. We partner with schools and districts nationwide to provide extraordinary training and support for teachers and to give students the resources they need to develop and demonstrate knowledge and skills that will propel them throughout their lives."

National Math and Science Initiative Research: https://www.nms.org/Our-Impact/Research.aspx

National Science Teachers Association: http://www.nsta.org

From the website: "The National Science Teachers Association (NSTA), founded in 1944 and headquartered in Arlington, Virginia, is the largest organization in the world committed to promoting excellence and innovation in science teaching and learning for all. NSTA's current membership of 50,000 includes science teachers, science supervisors, administrators, scientists, business and industry representatives, and others involved in and committed to science education."

Next Generation Science Standards (NGSS): https://www.nextgenscience.org/

From the website: "The Next Generation Science Standards (NGSS) are K–12 science content standards. Standards set the expectations for what students should know and be able to do. The NGSS were developed by states to improve science education for all students.

A goal for developing the NGSS was to create a set of research-based, up-to-date K–12 science standards. These standards give local educators the flexibility to design classroom learning experiences that stimulate students' interests in science and prepares them for college, careers, and citizenship."

Methods

Keywords and Search Strings

The following keywords and search strings were used to search the reference databases and other sources:

- science AND instruction AND (impact OR outcome*) AND (secondary OR "high school")
- science AND instruction AND ("project-based" OR "inquiry-based" OR "design-based") AND learning AND (impact OR outcome*) AND (secondary OR "high school")

Databases and Resources

We searched ERIC, a free online library of more than 1.6 million citations of education research sponsored by the Institute of Education Sciences (IES), for relevant resources. Additionally, we searched the academic database ProQuest, Google Scholar, and the commercial search engine Google.

Reference Search and Selection Criteria

In reviewing resources, Reference Desk researchers consider—among other things—these four factors:

- Date of the publication: Searches cover information available within the last ten years, except in the case of nationally known seminal resources.
- Reference sources: IES, nationally funded, and certain other vetted sources known for strict attention to research protocols receive highest priority. Applicable resources must be publicly available online and in English.
- Methodology: The following methodological priorities/considerations guide the review and selection of the references: (a) study types—randomized controlled trials, quasi experiments, surveys, descriptive data analyses, literature reviews, policy briefs, etc., generally in this order; (b) target population, samples (representativeness of the target population, sample size, volunteered or randomly selected), study duration, etc.; (c) limitations, generalizability of the findings and conclusions, etc.
- Existing knowledge base: Vetted resources (e.g., peer-reviewed research journals) are the primary focus, but the research base is occasionally slim or nonexistent. In those cases, the best resources available may include, for example, reports, white papers, guides, reviews in non-peer-reviewed journals, newspaper articles, interviews with content specialists, and organization websites.

Resources included in this document were last accessed on December 7, 2018. URLs, descriptions, and content included here were current at that time.

This memorandum is one in a series of quick-turnaround responses to specific questions posed by education stakeholders in the Appalachia region (Kentucky, Tennessee, Virginia, and West Virginia), which is served by the Regional Educational Laboratory Appalachia (REL AP) at SRI International. This Ask A REL response was developed by REL AP under Contract ED-IES-17-C-0004 from the U.S. Department of Education, Institute of Education Sciences, administered by SRI International. The content does not necessarily reflect the views or policies of IES or the U.S. Department of Education, nor does mention of trade names, commercial products, or organizations imply endorsement by the U.S. government.