Title: Research and resources on inquiry-based math instruction

Date: February 2010

Question: Could you provide research on using inquiry and problem-solving for teaching math in grades K-8?

Response:

Inquiry-based instruction is a teacher-guided instructional approach that engages students in investigating real world questions that they choose within a broad thematic framework. According to the National Academy of Sciences[1], when students learn through inquiry, they: question; investigate; use evidence to describe, explain, and predict; connect evidence to knowledge; and share findings. We conducted a search for resources in inquiry-based math instruction using the Education Resources Information Center (ERIC), the National Center on Instruction, Doing What Works, Google and Google Scholar, and by contacting WestEd colleagues. Several references and curricular and professional development are provided below. Abstracts or excerpts (provided by the author or URL) and links (where available) also are provided.

Publications

Alvarado, A. E., & Herr, P. R. (2003). *Inquiry-based learning using everyday objects: Hands-on instructional strategies that promote active learning in grades 3–8.* Thousand Oaks, CA: Corwin Press, Inc. Available at http://www.corwinpress.com

Abstract: This book explores the concept of using everyday objects as a process initiated both by students and teachers, encouraging growth in student observation, inquisitiveness, and reflection in learning. After "Introduction: Welcome to Inquiry-Based Learning Using Everyday Objects (Object-Based Inquiry)," there are nine chapters in two parts. Part 1, "Object-Based Learning," includes: 1) "What is Object-Based Inquiry?" (e.g., the reality of object-based learning and reasons to use it); 2) "How Do I Gather Collections?" (e.g., getting started and expanding and exploring one's collections); 3) "How Do I Get Started?" (e.g., planning in the classroom, grouping students, and planning lessons); 4) "Where Do I Start with Planning?" (e.g., developing essential understandings, identifying specific objects, locating objects, and question development); and 5) "How Do I Assess?" (e.g., formative and summative assessment). Part 2, "Lesson Plans," includes: 6) "Language Lesson Plans" (e.g., why tigers have stripes and what makes a poem perfect); 7) "Science Lesson Plans" (e.g.,

[1] National Committee on Science Education Standards and Assessment, National Research Council (1995). *National Science Education Standards, First Printing*. Washington, D.C.: National Academies Press.

birds of a feather and animal tracks); 8) "Social Studies Lesson Plans" (e.g., artifacts and plants); and 9) "Math Lesson Plans" (e.g., architectural geometry and fractions).

Carr, J., Carroll, C., Cremer, S., Gale, M., Lagunoff, R., & Sexton, U. (2009). *Making mathematics accessible to English learners: A guidebook for teachers, grades 6–12*. San Francisco: WestEd. Available at http://www.wested.org/cs/we/view/rs/945

Abstract: This practical book helps upper elementary, middle, and high school mathematics teachers effectively reach English learners in their classrooms. Designed for teachers who have had limited preparation for teaching mathematics to English learners, the guide offers an integrated approach to teaching mathematics content and English language skills, including guidance on best instructional practices from the field, powerful and concrete strategies for teaching mathematics content along with academic language, and sample lesson scenarios that can be implemented immediately in any mathematics class. It includes:

- Rubrics to help teachers identify the most important language skills at five ELD levels
- Practical guidance and tips from research and the field
- Seven scaffolding strategies for differentiating instruction
- Seven tools to promote mathematical language
- Assessment techniques and accommodations to lower communication barriers for English learners
- Three integrated lesson scenarios demonstrating how to combine and embed these various strategies, tools, techniques, and approaches

Chapter topics include teaching inquiry-based mathematics, understanding first and second language development, teaching the language of mathematics, scaffolding mathematics learning, and applying strategies in the classroom.

Evans, N. (2001). Inquiry-based professional development: Letting questions direct teachers' learning. *Voyages in Mathematics and Science, 26.* Available at http://www.prel.org/products/Voyages/dec01.pdf

Abstract: The feature article of this newsletter issue describes a course designed for the professional development of math teachers that uses inquiry-based classroom learning and presents articles on inquiry-based science and mathematics teaching. Other articles include: 1) "An Inquiry-Based Mathematics Classroom" (Lesley Lee); 2) "Teaching Science as Inquiry" (Donald B. Young); 3) "Learning about the Environment in American Samoa" (Donna L. Tiapula); 4) "More Teachers in American Samoa Join the GLOBE Program" (Elise Leroux); 5) "Project DELTA Holds Third Regional Institute" (A.J. Sandy Dawson); 6) "PREL/ENC Pacific Access Centers for Mathematics and Science Educators" (Alice Borja); 7) "The Pacific Consortium Welcomes the New PEIRS"; 8) "Mathematical Challenges" (A.J. Sandy Dawson); and 9) "PRISM Science: An Inquiry-Based Institute for Science Educators" (Elise Leroux). Solutions/Answers for "Mathematical Challenges" are included.

Goldston, M. J. (Ed.) (2004). *Stepping up to science and math*. Arlington, VA: National Science Teachers Association. Available at http://www.nsta.org

Abstract: *Stepping Up to Science and Math* invites teachers to step back and rethink the way they teach both of these essential subjects. Then it illustrates how teachers can step up the pace with standards-based activities that make learning more effective and efficient. (New

lessons featuring gummy worms, school buses, or the planet Mars help teachers step outside the normal.) Compiled from *Science & Children*, NSTA's award-winning elementary school journal, *Stepping Up* gathers 21 articles that provide interdisciplinary options for linking inquiry-based activities to mathematics as well as other K–6 curriculum areas, such as language arts and social studies. The book is organized into three broad content areas based on subject matter or skills: 1) Making connections among the basic process skills — such as linear measurement, data collection, estimation, and graphing — that underpin both science and math. Chapter titles include "Say Yes to Metric," "Gummy Worms Measurement," and "Weighing Dinosaurs"; 2) Using scientific concepts as the core for authentic investigations that link to other disciplines. Titles cover "Crossing the Curriculum with Frogs," "Real Earthquakes, Real Learning," and "Mission to Mars"; and 3) Finding contemporary applications for scientific inquiry and experimentation to develop more advanced integrated process skills. Among the titles: "The Scoop on Science Data," "Thinking Engineering," and "Building Structures." To make the book easy to use, each article is labeled by grade level, skills and concepts, standards addressed, and content connections. Best of all, every activity is "teacher tried-and-true." Practicing educators have validated the value of each one for teachers who've despaired of having no time for science — until now.

Kopp, J., & Bergman, L. (1999). *The rainbow of mathematics: A Great Explorations in Math and Science (GEMS) handbook for educators.* Berkeley, CA: University of California, Berkeley, GEMS, Lawrence Hall of Science #5200.

Abstract: This handbook features a presentation that summarizes the main ideas and current approaches in inquiry-based, content-rich mathematics education. This presentation is a product of Great Explorations in Math and Science (GEMS) professional development efforts, and has been used with teachers, administrators, parents, and at diverse community gatherings. It also defines the main mathematics strands in the GEMS series, articulates how math is interwoven throughout many GEMS guides, and demonstrates the strong alignment of GEMS units with national mathematics standards such as those set forth by the National Council of Teachers of Mathematics (NCTM).

Lynch, P. (2001). Salting the oats: Using inquiry-based science to engage learners at risk. *Primary Voices K–6, 10*(1), 16–22.

Abstract: Considers how due to the emphasis of reading, writing, and math, low-performing students are pulled from their regular classes for one-on-one tutorial sessions, restricting their exposure to group discussions and activities that encourage higher-order thinking skills. Suggests a reshaping of remedial curricula based on six guidelines.

Marshall, J. C., Horton, R., Igo, B. L., & Switzer, D. M. (2009). *K–12 science and mathematics teachers' beliefs about and use of inquiry in the classroom*. New York: Springer. Available at http://www.springerlink.com/content/288464x416n77468/

Abstract: A survey instrument was developed and administered to 1,222 K–12 mathematics and science teachers to measure their beliefs about and use of inquiry in the classroom. Four variables (grade level taught, content area taught, level of support received, and self-efficacy for teaching inquiry) were significantly correlated to two dependent variables, percentage of time that students are engaged in inquiry during a typical lesson, and the perceived ideal percentage of instructional time that should be

devoted to inquiry. Specifically, elementary school teachers reported using inquiry-based practices more than either middle school or high school teachers; similarly, elementary school teachers believed such practices should be used more often. All groups, however, reported believing in an ideal percentage of time devoted to inquiry instruction that was significantly greater than their reported percentage of time actually spent on inquiry instruction. A disordinal effect was found between grade level taught and content area taught; at the elementary level, science teachers reported both an ideal and actual percentage of time on inquiry higher than those reported by the math teachers, while at the high school level, math teachers reported both an ideal and actual percentage of time on inquiry higher than those reported by the science teachers. No correlations were found between typical and ideal percentage of time devoted to inquiry and subject matter content knowledge training, gender, years of teaching experience, or maximum degree earned.

McAllister, B. A., & Plourde, L. A. (2008). Enrichment curriculum: Essential for mathematically gifted students. *Education, 129*(1), 40–50.

Abstract: Research shows that mathematically gifted students learn differently from their same age group peers. They require curriculum to be differentiated to meet their specific learning styles. Studies have shown that formal instruction in elementary school classrooms often lacks challenge for the gifted learner since courses in regular classrooms sometimes have a relatively narrow range of topics, minimal investigation of concepts, repeated drill and practice, and yearly repetition. This paper highlights the need for an enriched elementary math curriculum that takes the regular classroom curriculum to a more contextual level. Inquiry-based, discovery learning approaches that emphasize open-ended problem solving with multiple solutions or multiple paths to solutions are what mathematically gifted students need to be successful. The process for creating this type of mathematical unit of study is described.

Ramsey, S., Neathery, F., Fholer, G., Weger, E., Voth, B., Townsend, J., Campbell, D., & Boedecker, M. (1999, February). *Master teachers in residence: Bringing a classroom perspective to course reform for NSF's Oklahoma Teacher Education Collaborative (O-TEC)*. Paper presented at the annual meeting of the American Association of Colleges for Teacher Education, Washington, DC. Available at http://www.eric.ed.gov/ERICDocs/data/ericdocs2sql/content_storage_01/0000019b/80/29/c1/7c.pdf

Abstract: Master teachers can be influential in course revision. The Oklahoma Teacher Education Collaborative (O-TEC) teacher reform effort is a consortium of nine higher education institutions working with the National Science Foundation's (NSF's) reform effort to produce teachers better equipped for teaching science and mathematics. The reform emphasizes inquiry-based instruction for all teacher preparation courses. O-TEC plans to pursue systemic enhancement of teacher preparation by providing innovative teacher recruitment, reform of the undergraduate curriculum, and increased emphasis on retaining new teachers. Its programs are designed to attract, train, and retain teachers. O-TEC features summer academies that provide model teaching experiences for potential teachers. The program has multiple entry points. Each O-TEC institution has added a Master-Teacher-in-Residence to the faculty to assist in course redesign and participate in team instruction. These master teachers liaison with the community, develop connections with local school districts, observe classes, provide beginning teacher support, reform

undergraduate block classes and methods courses, research causes of student failure, improve math labs, and plan summer institutes. Each institution has a site plan to enhance courses in science, mathematics, and education for preservice teachers. The revised courses reflect best practices in teaching and apply to real-world settings. Inservice programs for beginning teachers reinforce concepts taught during preservice instruction. O-TEC institutions stress the use of technology in preservice training and classrooms.

Curriculum

Math in a Cultural Context (MCC) is a supplemental elementary school math series, available at http://www.uaf.edu/mcc/. The math modules that compose MCC are the result of a rather extraordinary collaboration of educators, Yup'ik elders and teachers, mathematicians and math educators, and Alaskan school districts. This collaboration spans nearly two decades of work: forming meaningful relationships between the parties of this work to producing not only culturally relevant materials that connect local knowledge to school knowledge, include integrated materials (literacy, geography, and science), and, according to rigorous experimental and quasi-experimental designs used in numerous studies, found MCC to be effective. MCC consists of:

- 9 supplemental math modules from 2nd grade to 7th grade
- 8 stories that accompany the modules
- CDs and DVDs that show exemplary cases of teachers using MCC to elders' demonstrating their knowledge
- a *Guide to Using MCC* is in preparation

Math and science professional development resources from WestEd

Math Pathways and Pitfalls
http://www.wested.org/cs/we/view/pj/81
Math Pathways and Pitfalls (MPP) provides professional development for teachers, and intervention lessons for students in grades K–8. Together they address the need for improving instruction of key mathematical standards and learning pitfalls, regardless of the core instructional materials being used. There are four books with 20 to 22 lessons per book. The books for students in grades K–3 focus on whole number concepts, place value, and operations, while books for students in grades 4–8 focus on fractions, decimals, ratios, proportions, and percents. Algebra readiness is integrated into the lessons for students in grades 1–8. Professional development offerings include:

- Discussion Builders Workshop (K–8, any subject area)
- Institute for Teachers (K–8, math focus)

O'Brien Carlson, M., Humphrey, G. E., & Reinhardt, K. S. (2003). *Weaving science inquiry and continuous assessment: Using formative assessment to improve learning*. Thousand Oaks, CA: Corwin Press. Available at http://www.wested.org/cs/we/view/rs/704
Abstract: State and local tests are being increasingly used to document levels of learning and build accountability into the education system. But educators committed to learning for all need more than just standardized tests and end assessments. This book offers teachers and professional leaders tools for monitoring and improving student achievement

in the sciences. With over a decade of experience working with hundreds of science teachers, the authors have developed a program that enables teachers to identify difficult areas of student learning and to modify teaching strategies to further student success. This constant assessment also allows teachers to identify troublesome concepts and address them before the state and local assessments are given and the results tabulated. Through clear examples — supported by research — the authors provide a rationale and practical tools for weaving continuous assessment and reflective instruction into the fabric of science learning.

Supporting High Quality Science Teaching, Learning, and Continuous Assessment
http://www.wested.org/cs/we/view/serv/89
Participants can expect to benefit from this Institute in the following ways:

- Deepen an understanding of inquiry-based teaching, learning, and assessment.
- Learn and practice the tools and techniques of continuous assessment; understand the role it plays in teacher decision-making, in deepening conceptual understanding, in teacher professional development, and in summative assessment.
- Enhance science content knowledge in a specific area, for example, "the principles of motion."
- Become more familiar with current science resources.
- Develop a plan for incorporating a key science content area, inquiry, and formative assessment into a school's curriculum.
- Build a network for support and colleagueship.

Teachers as Learners
http://www.wested.org/tal/five_film_categories/IMMERSION/scientific-inquiry.html
This example of professional development takes place at the Exploratorium's Institute for Inquiry in San Francisco, California. Participants are engaged in inquiry into physical science concepts, guided by facilitators Barry Kluger-Bell, Fred Stein, Doris Ash, and Marilyn Austin. The participants are leadership teams from different school districts from around the U.S.

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