STEM Topic: Informal Science Education and K-12 School Education

Maltese, A.V., Tai, R.H. 2011. Pipeline persistence: Examining the association of educational experiences with earned degrees in STEM among U.S. students. Wiley Periodicals, Inc. Science Education. 1-31.

> As the global economic crisis continues, sustaining the United States' position as a leader in research and development is a top concern of policy makers. Looking to increase the number of students pursuing degrees in STEM (science, technology, engineering, and mathematics), calls for improved mathematics and science education abound. We completed a two-part analysis to assess the school-based factors related to students choosing to complete a major in STEM. The results indicate that the majority of students who concentrate in STEM make that choice during high school, and that choice is related to a growing interest in mathematics and science rather than enrollment or achievement. These results indicate that the current policy focus on advanced-level course taking and achievement as measures to increase the flow of students into STEM may be misguided.

Moss, K., Crowley, M. 2011. Effective learning in science: The use of personal response systems with wide range of audiences. Computers & Education. Vol. 56, 36-43.

> This paper describes the flexibility of Personal Response Systems (PRSs), (also known as 'clickers' or electronic voting systems (EVS)), as part of strategies to support students' learning in science. Whilst variants of this technology began to appear 12 years ago, there is now a steadily increasing adoption of these systems within higher education, including science programmes, and this use has grown significantly in the last six years. They have previously been shown to offer a measurable learning benefit. Typically, someone at an institution buys these systems for learning support and they never make it out of their cases. Far less work has been done with these systems at school level. In this practitioner based paper, the broad range of practical uses for these systems is described in a variety of formal and informal learning situations – from testing the understanding of science concepts (from primary aged school children up to physics undergraduates), to undertaking evaluation of events as well as public participation in data collection for research on attitudes to careers. In addition, the data collected on such handsets can be mapped to demographic factors such as gender and age yielding further layers of analysis. Overall this is a highly flexible and transferable approach to the use of interactive technology for engaging learners of all ages as well as carrying out research.

Ainsworth, H.L., Eaton, S.E. 2010. Formal, non-formal and informal learning in the sciences. Onate Press, Eaton International Consulting, Canada. 48.

> This research report investigates the links between formal, non-formal and informal learning and the differences between them. In particular, the report aims to link these notions of learning to sciences and engineering in Canada and the United States. Examples are given for each of these types of learning in different scientific contexts, including basic scientific literacy at one of the scale and professional organizations at the other end of the scale.

Bannier, B.J. 2010. Motivating and assisting adult, online chemistry students: A review of the literature. J. Sci Educ Technol. Vol. 19, 215-236.

While comprehensive texts, articles, and literature reviews presenting research in the singular arenas of motivation, help-seeking, and online science learning are relatively easy to find, syntheses and interactions between these constructs are lacking. Part I of this review addresses this knowledge gap by drawing together key research from the domains of educational psychology and adult education, addressing the constructs of motivation, self-efficacy, adult learning, and help-seeking. Part II of this review extends and applies the motivation and help-seeking discussion to the emerging and exciting field of online chemistry education. The result is a comprehensive synthesis of the strengths and limitations of the currently existing body of knowledge related to the motivation and help-seeking behaviors of adult, online chemistry students.

Corner, A., Hahn, U. 2009. Evaluating science arguments: Evidence, uncertainty, and argument strength. Journal of Experimental Psychology: Applied. Vol. 15, 199-212.

Public debates about socioscientific issues are increasingly prevalent, but the public response to messages about, for example, climate change, does not always seem to match the seriousness of the problem identified by scientists. Is there anything unique about appeals based on scientific evidence—do people evaluate science and nonscience arguments differently? In an attempt to apply a systematic framework to people's evaluation of science arguments, the authors draw on the Bayesian approach to informal argumentation. The Bayesian approach permits questions about how people evaluate science arguments to be posed and comparisons to be made between the evaluation of science and nonscience arguments. In an experiment involving three separate argument evaluation tasks, the authors investigated whether people's evaluations of science and nonscience arguments differed in any meaningful way. Although some differences were observed in the relative strength of science and nonscience arguments, the evaluation of science arguments was determined by the same factors as nonscience arguments. Our results suggest that science communicators wishing to construct a successful appeal can make use of the Bayesian framework to distinguish strong and weak arguments.

Schwartz, M.S., Sadler, P.M., Sonnert, G., Tai., R.H. 2009. Depth versus breadth: How content coverage in high school science courses relates to later success in college science coursework. Wiley Periodicals, Inc., Science Education. Vol. 93, 798-826.

This study relates the performance of college students in introductory science courses to the amount of content covered in their high school science courses. The sample includes 8310 students in introductory biology, chemistry, or physics courses in 55 randomly chosen U.S. colleges and universities. Students who reported covering at least 1 major topic in depth, for a month or longer, in high school were found to earn higher grades in college science than did students who reported no coverage in depth. Students reporting breadth in their high school course, covering all major topics, did not appear to have any advantage in chemistry or physics and a significant disadvantage in biology. Care was taken to account for significant covariates: socioeconomic variables, English and mathematics proficiency, and rigor of their preparatory high science course. Alternative operationalizations of depth and breadth variables result in very similar findings. We conclude that teachers should use their judgment to reduce coverage in high school science courses and aim for mastery by extending at least 1 topic in depth over an extended period of time.

Bralower, T.J., Feiss, P.G., Manduca, C.A. 2008. Preparing a new generation to face Earth's future. Liberal Education. Spring. 20-25.

> As the research interests and the focus of traditional earth scientists are transformed, so too must education in earth system science at colleges and universities across the country change. The required change involved not only the methods we use to teach this new science, but also the essential place of the earth sciences in the panoply of disciplines as traditionally ordered by our academic colleagues. With growing public and political awareness of the significant environmental problems facing the earth in the coming decades, and the realization that issues such as global warming require action on the part of individuals as well as governments, earth system science must establish its place in college curricula to ensure that a new generation of citizens and scientists is prepared to meet future challenges. To earth scientists, all of this is self-evident. But it is not always so within the broader communities of the academy. We hear, for example, that the twenty-first century will be the "Century of Biology." Earth science courses, faculty, and departments are often the first casualties of financial exigency and budget insufficiency. Is it possible that in 2050 we will find ourselves wrestling with an earth system we only partially understand as human impacts tip us toward climate, ecosystem, and resource crises of literally life-threatening or apocalyptic dimensions?
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> We posit that strong research in earth system science and equally strong investments in both teaching the earth sciences and training a new generation of earth system scientists are not optional but essential. The handwriting is on the wall: we have only one earth; we are engaged in a dangerous experiment that involves altering the dynamics of earth systems upon which we are wholly dependent; we do not fully understand how the system works, and we are only beginning to be able to predict our effect on that system.

Trefil, J. 2008. Science education for everyone. Why and What? Liberal Education. Spring. 6-12.

> The most important use our students will make of whatever science they acquire will be in their future role as citizens

Nehm, R. H., Schonfeld, I.S. 2007. Does increasing biology teacher knowledge of evolution and the nature of science lead to greater preference for the teaching of evolution in schools? J Sci Teacher Ed. Vol 18, 699-723.

> This study investigated whether or not an increase in secondary science teacher knowledge about evolution and the nature of science gained from completing a graduate-level evolution course was associated with greater preference for the teaching of evolution in schools. Forty-four precertified secondary biology teachers participated in a 14-week intervention designed to address documented misconceptions identified by a precourse instrument. The course produced statistically significant gains in teacher knowledge of evolution and the nature of science and a significant decrease in misconceptions about evolution and natural selection. Nevertheless, teachers' postcourse preference positions remained unchanged; the majority of science teachers still preferred that antievolutionary ideas be taught in school

Wieman, C. 2007. Why not try. A scientific approach to science education. Change. September/October. 9-16.

The purpose of science education is no longer simply to train that tiny fraction of the population who will become the next generation of scientists. We need a more scientifically literate populace to address the global challenges that humanity now faces and that only science can explain and possibly mitigate, such as global warming, as well as to make wise decisions, informed by scientific understanding, about issues such as genetic modification. Moreover, the modern economy is largely based on science and technology, and for that economy to thrive and for individuals within it to be successful; we need technically literate citizens with complex problem-solving skills.

In short, we now need to make science education effective and relevant for a large and necessarily more diverse fraction of the population. What do I mean by an effective education in science? I believe a successful science education transforms how students think, so that they can understand and use science like scientists do. (See Figure 1). But is this kind of transformation really possible for a large fraction of the total population?

Winter, D. 2007. Infusing mathematics with culture: Teaching technical subjects for social justice. New Directions for Teaching and Learning. Fall. 97-108.

For more than twenty years the undergraduate mathematics teaching community has conducted a deep conversation concerning the pedagogies appropriate for introductory mathematics courses, including college algebra, precalculus, and calculus (Ganter, 2000, 2001). Fueling this ongoing discussion has been the recognition that students' failure to "acquire a deep understanding of the material they are supposed to learn in their [mathematics] courses" (Graesser, Person, and Hu, 2002, p. 33) is still unacceptably common (Bookman and Friedman, 1994; Selden, Mason, and Selden, 1989; Smith, 1998).

This conversation has produced changes in the pedagogy of many mathematics courses (Hurley, Koehn, and Ganter, 1999; Lutzer, Maxwell, and Rodi, 2002), including increased use of cooperative learning and technology to promote learning. Recognizing the value of student interest as a resource for learning (Schiefele and Csikszentmihalyi, 1995), many instructors have highlighted the applicability and usefulness of mathematical techniques for solving problems in the world outside the classroom (see Alper, Fendel, Fraser, and Resek, 1996; De Bock and others, 2003; Forman and Steen, 2000; Pollack, 1978; Walkerdine, 1988). One rationale for integrating social and cultural learning with traditional STEM learning is to use undergraduates' enthusiasm for social and political issues (National Survey of Student Engagement, 2004) as an engine to drive more abstract and conceptual mathematical learning (Carter and Brickhouse, 1989; Nix, Ryan, Manly, and Deci, 1999; Zoller, 1990).

Miller, J.D. 2004. Public understanding of, and attitudes toward, scientific research: what we know and what we need to know. Sage Publications, Public Understanding Science. Vol. 13, 273-294.

Over the last four decades, a substantial body of national survey material has been collected in the US concerning the public understanding of science and technology. Using this body of research, this analysis outlines the major trends from 1957 to 1999 and discusses their implications for public understanding of, and attitudes toward, scientific research. The analysis found that although the rate of civic scientific literacy in the US is only now approaching 20 percent, there is a strong and continuing public belief in the value of scientific research for economic prosperity and for the quality of life. Even though there are some continuing reservations about the pace of change engendered by science and technology and the relationship between science and faith, the public consistently reconciles these differing perceptions in favor of science.

Stigler, J.W., Hiebert, J. 2004. Improving mathematics teaching. Educational Leadership. February. 12-19.

> We have been working for 10 years on a research program aimed at answering questions related to the difference in mathematic classrooms around the globe. The TIMSS video studies document typical teaching practices in various countries. These studies employ the video survey, a novel methodology that combines two research traditions: qualitative classroom research and large-scale survey research. The video studies capture close-up pictures of the classroom processes used by national samples of 8th grade mathematics teachers in different countries. These teachers are not necessarily experienced or effective. They are ordinary teachers, teaching lessons that they routinely teach.

Byrnes, J.P. 2003. Factors predicative of mathematics achievement in white, black and Hispanic 12th graders. J. of Educ Psychology. Vol. 95, 316-326.

> In this study, a secondary analysis of the National Assessment of Educational Progress was conducted to provide insight into ethnic differences in 12th-grade math achievement. Using the 3 conditions model (3C model) of achievement as a guide, regression analyses showed ethnicity accounted for less than 5% of the variance in math performance once indices of socioeconomic status, exposure to learning opportunities, and motivation were controlled. In contrast, variables central to the 3C model accounted for 45%–50% of the variance. The implications of these results for theories of ethnic differences and for reform efforts are discussed. The findings suggest that schools can do a great deal to close achievement discrepancies among White, Black, and Hispanic students.

Roth, W.M., Lee, S. 2002. Scientific literacy as a collective praxis. Public Understanding Science. Vol. 11, 33-56.

> In this article, we conceive of scientific literacy as a property of collective activity rather than individual minds. We think of knowing and learning science as situated in and distributed across social and material aspects of a setting. To support the proposed conception, we provide several detailed cases from our three-year multi-site ethnographic study of science in one community, featuring different types of citizens who walk a creek, interact during an environment-oriented open-house event, discuss water problems, collect data, and have different conceptions of human-environment relations. The case studies show that collectively, much more advanced forms of scientific literacy are produced than any individual including scientists could produce. Creating opportunities for scientific literacy to emerge from collective activity, irrespective of whether one or more participants know some basic scientific facts, presents challenges to science educators very different from teaching basic facts and skills to individuals.

Zimmerman, C., Bisanz, G.L., Bisanz, J., Klein, J.S., Klein, P. 2001. Science at the supermarket: a comparison of what appears in the popular press, experts' advice to readers, and what students want to know. Institute of Physics Publishing, Public Understanding Science. Vol. 10, 37-58.

The popular print media constitute a major source of new information about scientific research for the public and for members of the scientific community outside their areas of expertise. Despite the potential importance of media reports to scientific literacy and public awareness of science, little is known about the content of these articles. We sampled the popular print media (e.g., publications such as those sold at a convenience store or supermarket) and found that the majority of articles about scientific research were in the form of news briefs. We analyzed and compared 9a) the content of these news briefs, 9b) advice given by experts about how to read media reports about science critically, and (c) university students' requests for information as they evaluated brief reports about research. Some marked discrepancies were found. For example, much of the information that experts advised readers to attend to or that students spontaneously requested for conceptualizing scientific literacy, as well as for changing science journalism and science education in ways that can enable readers to become effective consumers of scientific information

Trend, R. 1998. An investigation into understanding of geological time among 10- and 11-year-old children. Int. Jour. Sci Educ. Vol. 20, 973-988.

This research focused on the understanding of geological time among UK children aged 10 and 11 years. The empirical study, in two stages, involved total of 189 children in activities designed to reveal knowledge and understanding of geological time. The preliminary study with 12 children was designed to identify the most powerful and appropriate techniques to use in the Main Study. It also resulted in some findings concerned with the place of deep time in children's conceptualization of Earth events. The Main Study, with 177 children, involved the sequencing of geological events in three separate but almost identical tasks. Results indicate that children of this age have a general awareness of major events such as the Ice Age and moving continents, but that a clear chronology is almost entirely lacking. Children conceive of events as filling into two distinct time zones: the 'extremely ancient' and the 'less ancient'.

Lampert, M. 1990. When the problem is not the question and the solution is not the answer: Mathematical knowing and teaching. American Educational Research Journal. Vol. 27, 29-63.

This paper describes a research and development project in teaching designed to examine whether and how it might be possible to bring the practice of knowing mathematics in school closer to what it means to know mathematics within the discipline by deliberately altering the roles and responsibilities of teacher and students in classroom discourse. The project was carried out as a regular feature of lessons in fifth-grade mathematics in a public school. A case of teaching and learning about exponents derived from lessons taught in the project is described and interpreted from mathematical, pedagogical, and sociolinguistic perspectives. To change the meaning of knowing and learning in school, the teacher initiated and supported social interactions appropriate to making mathematical arguments in response to students' conjectures. The activities students engaged in as they asserted and examined hypotheses about the mathematical structures that underlie their solutions to problems are contrasted with the conventional activities that characterize school mathematics.