Science Readiness of College Freshmen: Implications to Inquiry-Based Science Instruction

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Abstract

College readiness provides foundation of knowledge and skills to allow future workers to adapt to the changing requirements of the Information and Communication Technology (ICT)-driven workplace. Science literacy has become a necessity for everyone because society is increasingly dependent on Science and Technology. This descriptive quantitative study aims to determine competency level of incoming freshmen in Science as measure of their college science readiness and to describe how it can possibly influence inquiry-based Science instruction. Ratings in a teacher-made Science test covering Nature of Science, Life Sciences, Chemistry, Physics and Earth and Space Science were used. Science items were categorized by cognitive domains such as factual knowledge, conceptual understanding, and reasoning and analysis. Results showed that the group Mastered the knowledge domain of Physics only while the other subareas by science cognitive domain were either Least learned or Nearly Mastered at most. The group performed Least in Life Sciences followed by Chemistry. Subareas in Science are positively associated with each other. The same pattern is observed in the different cognitive domains. Analyzing and associating the results with the students' readiness for inquiry-based Science instruction, teachers can comfortably employ inquiry in the classroom for groups who have at least nearly mastered different areas in Science. While this pedagogical approach is highly recommended to develop critical, logical, and creative thinking among students, it requires some Science basic skills for it to be effective particularly in reasoning and analysis.

Keywords: college admission test, college Science readiness, Inquiry-based Science instruction, Science competency level

Assessment provides feedback to the learner and the teacher. It bridges the gap between expectations and reality. Assessment can gauge the learners' readiness to extend their knowledge in a given area. It can measure knowledge gains, identify needs, and determine the learners' ability to transfer what was learned to a new setting (ACT, 2008). When teachers use assessment tools to gather information about their students, then modify instruction accordingly, the assessment process becomes an integral part of teaching and learning. Using an assessment to inform instruction can help teachers create a successful learning environment. Students learn over time and in various contexts. It is important to use a variety of instructional methods and materials to meet students' diverse needs. Assessment will help strengthen and build upon their knowledge and skills.

In a higher education institution, results of college admission test are analyzed and disseminated to teachers and the management. It can, hopefully, help teachers and administrators guide the education of incoming college students. Since this university implements block scheduling of classes, i. e. students in a section of the same specialization will always be classmates in the general education classes and the major subjects, the information about their entry competencies as freshmen may be helpful in designing and developing teaching approaches appropriate for their base knowledge and skills. While college subjects have prescribed coverage, teachers can adjust to the groups' capability and readiness. Very critical are their college Mathematics and English language arts readiness. In science, there are no prerequisites as to what students should take as entry-level science courses. Among students who are interested in Science, there are those who go to college and experience success. However, there is still a large number of students initially interested in science or Science, Technology, Engineering and Mathematics (STEM) careers who drop their freshman course or change to non-science programs presumably due to poor preparation (Next Generation Science Standards [NGSS], 2013).

The global economy needs scientifically literate graduates to support technically-based industries. Exline (2004) says that the future of our country's success now depends on the workforce that works smarter. Hence, science-ready college freshmen are critical in producing higher order scientific literacy for the workplace. The Next Generation Science Standards (Achieve, Inc., 2013), state that college readiness in Science include asking questions, developing and using models, planning and carrying out investigations, analyzing and interpreting data, and using mathematics and computational thinking in scientific applications.

Preparing students for college has become a national educational policy as a growing number of school systems make college readiness part of their goals. College readiness is a set of skills, behaviors, attitudes, and knowledge, both cognitive and noncognitive, possessed by the individual students who shape their likelihood of attaining a college degree (Nagaoka, et al, 2013). Students need to know more; they need to be better equipped to apply knowledge to tackle increasingly complex issues and problems, whether they are 'college-bound' or 'work-bound' (Achieve, 2008). For instance, according to ACT (2015) report, in the United States, academic achievement as measured by ACT College Readiness Benchmark attainment, has a clear and distinctive relationship with the path taken by high school graduates. Those who were more academically ready were more likely to enroll in four-year institutions. Graduates who enrolled in two-year colleges or pursued other options after high school were more likely to have met fewer benchmarks. For the sizeable number of 2015 graduates who did not meet any benchmarks, their post-high school opportunities appear to have been limited compared to their college-bound peers. For the 2015 ACT-tested high school graduates, 28% met all benchmark areas.

When in college, how do we sustain and develop to higher levels these competencies and other critical skills? Jarrett (1997) reported that students when taught in effective inquiry-based learning environments improve skills and exhibit more positive attitudes towards science. In addition, research indicates that an inquiry-based instruction in science improves skills in laboratory procedures, graphing and interpreting data, oral communications, and critical thinking. Students develop a scientific approach to problem solving. Moreover, students' understandings and abilities in Science are grounded in the experience of inquiry. Inquiry is the foundation for the development of understandings and abilities of the other content courses. Students need solid knowledge and understanding in physical, life and earth and space science if they are to apply science (National Research Council [NRC], 1996).

Science as inquiry is basic to science education and a controlling principle in the ultimate organization and selection of students' activities. The standards on inquiry highlight the ability to conduct inquiry and develop understanding about scientific inquiry. Students at all grade levels and in every domain of science should have the opportunity to use scientific inquiry and develop the ability to think and act in ways associated with inquiry. Such include asking questions, planning and conducting investigations, using appropriate tools and techniques to gather data, thinking critically and logically about relationships between evidence and explanations, constructing and analyzing alternative explanations, and communicating scientific arguments. The science and technology standards establish connections between the natural and designed worlds and provide students with opportunities to develop decision-making abilities. As a complement to the abilities developed in the science as inquiry standards, these standards call for the students to develop abilities to identify and state a problem, design a solution-including a cost and risk-and-benefit analysis – implement a solution, and evaluate the solution.

Science instruction should reflect the way that science is practiced in the real world (Willoughby, 2005). When students use inquiry and become active participants in asking questions, designing procedures, carrying out investigations, and analyzing data, they take responsibility for their own learning and begin to think like scientists. Engaging students in inquiry helps them to make a critical link between understanding science as a process, and understanding scientific concepts. Inquiry requires students to do more than observe, infer, and experiment. It requires them to combine scientific processes with content knowledge and to use scientific reasoning and critical thinking to develop their understanding of science (NRC, 1996).

With the benefits of inquiry-based instruction, however, students should be prepared for science inquiry activities. They should know basic science facts and vocabulary. Without these facts, students can be left with the impossible task of reinventing knowledge, or they may construct seriously flawed understandings (Jarrett, 1997). These are some of the deterrents of the use of inquiry-based instruction as students may not be ready. A form of resistance by teachers to implement inquiry comes from the students themselves (Wenning, 2005). Hence, this study aims to discuss the science readiness of college students and its implications with the implementation of inquiry in the classroom.

Objectives

This study aims to determine Science performance of college freshmen in the College Admission Test (CAT) as a measure of their science readiness and discuss its potential implication on inquiry-based science instruction. Likewise, the study determined the association of the different science areas and the different science cognitive domains.

Methodology

The Participants

A sample of 1000 freshmen from the seven colleges/academic units of the University for SY 2009-2010, from an enrollment of 1463 was considered in this study. This sample constitutes 65.5% of the population.

The Research Design

Descriptive research design was employed. The scores in the College Admission Test which are in the data-based in the university was used to describe performance and college readiness of high school graduates in the absence of a national exit examination for graduating high school students.

The Instrument

In the University which was considered in the study, the College Admission Test is administered twice every school year and is periodically evaluated, improved, and revised. The examination instrument used for this academic period was a 250-item test in the following areas: English, Filipino, Mathematics, Science, and General Information. This study considered the 50-item Science part of the Admission Test which included the topics in the secondary Science subjects as Nature of Science, Earth and Space Science, Life Science, Chemistry, and Physics. The Science cognitive domains include factual knowledge, conceptual understanding, and reasoning and analysis. Factual knowledge is described as the knowledge of vocabulary, facts, information, symbols, units, and procedures of the discipline, particularly the sciences in this study. Conceptual understanding is the cognitive domain by which students exhibit a grasp of the relationships that explain the behavior of the physical world and relating the observable to more abstract or more general concepts. Reasoning and analysis involve breaking down of the problem into parts and evaluation of solutions, weighting of advantages and disadvantages of alternative materials and processes. This cognitive domain is needed for problem solving, developing explanations, drawing conclusions, making decisions, and extending one's knowledge to new and unfamiliar situations (Mullis, et al., 2003).

The test was designed and developed by a team of Science faculty and subjected to jurors' evaluation. The test was not standardized but was based on minimum competencies for secondary students that should have been acquired by college-bound students. A reliability coefficient of 0.79 was computed from the test results of the previous year. An item was categorized on the basis of the most complex cognitive ability required. Test scores were used to describe the groups' readiness for college academic work particularly in Science.

Procedure

High school graduates submitted their application for admission to the Office of Admissions at the University Registrar's Office. They were then given instruction sheets on how to report to rooms in the examination venue at the scheduled time and date. Test papers were corrected by designated personnel.

Test papers of enrolled freshmen were obtained from the Office of the University Registrar. Correct answers were marked. Mark of each item of the tests was encoded and subjected to data analysis. Each item in the test was analyzed by assigning 1 to the item correctly answered by the student; 0 if incorrectly answered. Averaging the scores may result to a proportion that indicates the proportion of the items correctly answered by the student.

Data Analysis

The binary data was encoded using SPSS. The group mean and standard deviation were computed for all items of the Science test when students were grouped by academic program and as a whole. The group mean represents the proportion of students in the specified group who correctly answered the item. Items were again grouped by subareas. Means of item means were also computed to represent the average proportion of students who correctly answered several items included in a subarea. The overall mean indicates the level of competency of the group in a particular subject area. The scale shown in Table 1 applies to group competency level.

Table 1

Scale of the Groups' Competency Level in the different Subject Areas in Science

Mean proportion	**% equivalent**	**Level of Competency on a subject matter**
<0.50	<50%	Least learned
0.50 to 0.749	50% to 74.9%	Nearly mastered
≥0.75	≥75%	Mastered

Results and Discussions

Table 2 summarizes the mean proportion of students who correctly answered Science items in the College Admission Test when students were taken as a whole and items were grouped by Science cognitive domain and subarea. Overall, the batch has not mastered the Science competencies included in the Science test as shown by the mean rating of 0.48 indicating that on the average, only 48% of the students correctly answered Science items. Comparing this result with the high school students in the United States, the 2014 ACT and Council for Opportunity in Education (COE) report indicated that 36% and 37% respectively of the ACT-tested graduates met the ACT Science Readiness Benchmark.

Table 2

Proportion of Students who Correctly Answered Science Items by Subareas by Cognitive Domains

Science subareas	Science Cognitive Domains			Overall Science test	Description
	Knowledge	Conceptual Understanding	Reasoning		
Nature of Science	0.47	0.52	0.54	0.51	Nearly Mastered
Earth & Space Science	0.62	0.49	0.42	0.51	Nearly Mastered
Life Science	0.49	0.40	0.33	0.41	Least Learned
Chemistry	0.48	0.52	0.44	0.48	Least Learned
Physics	0.75	0.64	0.40	0.60	Nearly Mastered
Overall Science test	0.55	0.51	0.42	0.48	Least Learned

Note: <0.50 = <50% = Least Learned; 0.50 to 0.749 = 50% to 74.9% = Nearly Mastered; ≥0.75 = ≥75% = Mastered

When items were classified by subarea, the batch has Nearly Mastered the Nature of Science, Earth/Space Science, and Physics given the mean rating of 0.51, 0.51, and 0.60, respectively, implying that on the average, 60% of the test-takers correctly answered Physics test items. The concepts on Life Sciences and Chemistry were Least Learned, on the average, as the batch posted mean ratings of 0.41 and 0.48, respectively. When items were grouped by cognitive domains, the batch has Nearly Mastered factual knowledge and conceptual understanding domains posting mean ratings of 0.55 and 0.51, respectively. Reasoning and analysis were Least learned at a mean rating of 0.42. This Science cognitive domain requires higher order thinking skills.

When items were categorized by subarea in Science and cognitive domains, students Mastered the factual knowledge domain of Physics as they posted a mean of 0.75; Nearly Mastered Conceptual understanding of the same subarea at 0.64 mean rating. Most of the subcategories are Least learned by students having posted mean ratings below 0.50 with the Reasoning and Analysis in Life Science as the lowest at 0.33. This seem to indicate relatively low Science readiness of students for college instruction. Probably, the Recency Effect could explain the relatively high ratings in Physics because it is the Science subject of the 4th year high school students. Moreover, Biology (Life Science) is studied in the second year so students may have difficulty retrieving information related to it. The Nature of Science concepts are generally included in the introduction of all Science subjects; hence, the Primacy Effect may explain why students performed comparatively better in Nature of Science. Primacy effect in learning means that we remember best what we learn first. Students performed least in the Reasoning and Analysis domain as it is the Least learned of all subareas except Nature of Science. This Science domain may not have been given enough focus in high school since it required more time for the students to do the activities. Teachers also need more time to prepare these activities that would pose more challenge on inquiry critical thinking skills of students.

Required in the tertiary level are Science subjects in general education that include Earth Science, Biological Sciences, Physical Science, and Science, Technology, and Society (STS). Other 4-year degree programs require Physics and General Chemistry. In most of these subjects, some tertiary instructors use inquiry-based instruction.

When students were grouped by their academic program, BS Nursing posted the highest mean rating of .62. The group has Nearly mastered all subareas in Science having attained mean rating above .50 but less than .75. See Table 3. The BS Information Technology, AB English, BS Biology, B Special Education, and B Secondary Education students also Nearly mastered all subareas except Life Science which was Least learned by each group. Almost all programs Nearly mastered Physics concepts except the BS Dev Communications and B Physical Education whose students have Least learned the concepts in all subareas covered in the Science test. AB Political Science, BS Applied Mathematics, B Tourism, BHRM, B Cooperatives Management, B Broadcasting, B Journalism, BS Dev Communications, and B Physical Education are programs requiring only Earth Science and Biological Sciences as their General Education science subjects. Results show that students of these programs have not mastered high school science concepts in general and Life Science concepts in particular. It is on these groups that Biological Science instructors have to be careful when implementing inquiry-based instruction and assigning inquiry-based learning projects. While there is evidence that inquiry–based instruction enhances student performance and attitudes towards science which are needed by these groups (Zhang & Li, 2007), skills-appropriate classroom inquiry should be applied. Teachers may face challenges in implementing inquiry-based teaching practices because many students are not used to figuring out so much on their own (Allen, 2006) that both teachers and students become frustrated with the outcomes. On the other hand, BS Nursing, BS Information Technology, AB English, BS Biology, B Special Education and B Secondary Education tend to have the necessary science background for them to engage in inquiry learning. If properly planned and implemented, students can benefit from this approach through better understanding of the nature of science, the acquisition of scientific knowledge and skills, and the cultivation of scientific habits of the mind. Effective inquiry-based experiences enable students to use scientific understanding to make informed decisions about personal and social issues (Fang, Lamme, & Pringle, 2010).

Table 3

Summary Statistics of the Proportion of Students who Correctly Answered Science Items by Subareas by Academic Program

Course/Academic Program		Subareas in Science					Overall Science test
		Nature of Science	Earth & Space Science	Life Science	Chemistry	Physics	
BS Nursing		0.68	0.66	0.52	0.63	0.7	0.62
BS Information Technology		0.65	0.58	0.46	0.54	0.68	0.56
AB English		0.57	0.55	0.42	0.57	0.65	0.53
BS Biology		0.54	0.54	0.44	0.52	0.63	0.52
BSpecial Education		0.52	0.53	0.42	0.52	0.64	0.51
B Secondary Education		0.52	0.53	0.43	0.5	0.61	0.5
AB Political Science		0.47	0.51	0.38	0.52	0.6	0.48
BS Applied Mathematics		0.51	0.53	0.4	0.44	0.63	0.48
BS Information System		0.48	0.56	0.37	0.49	0.57	0.48
B Elementary Education		0.49	0.5	0.39	0.46	0.62	0.47
B Tourism		0.48	0.49	0.38	0.45	0.57	0.46
B Hotel & Restaurant Management		0.45	0.47	0.39	0.44	0.56	0.45
B Cooperative Management		0.5	0.53	0.35	0.41	0.57	0.44
B Broadcasting		0.45	0.45	0.38	0.4	0.55	0.42
B Journalism		0.43	0.46	0.39	0.42	0.52	0.42
B Music Education		0.37	0.36	0.35	0.38	0.54	0.39
BS Developmental Communication		0.4	0.34	0.29	0.37	0.47	0.36
B Physical Education		0.41	0.38	0.31	0.32	0.46	0.36
Total	Mean	0.51	0.51	0.41	0.48	0.60	0.48
n=1000	SD	0.24	0.22	0.18	0.19	0.19	0.14

Note: <0.50 = <50% = Least Learned; 0.50 to 0.749 = 50% to 74.9% = Nearly Mastered; ≥0.75 = ≥75% = Mastered

When test items were grouped by Science cognitive domain, as presented in the summary result in Table 4, results show that students of almost all programs have Nearly Mastered the knowledge domain in Science except B Journalism, BMusic Education, BSDev Communication, and B Physical Education who least mastered this lower order domain. In addition to this group, B Broadcasting, B Cooperatives Management, and B Hotel & Restaurant Management have least mastered the conceptual understanding domain.

Table 4

Mean Proportion of Students who Correctly Answered Science Items by Cognitive Domains by Academic Program

Course/Academic Program		Subareas in Science			Overall Science test
		Knowledge	Conceptual Understanding	Reasoning	
BS Nursing		0.69	0.63	0.57	0.62
BS Information Technology		0.62	0.59	0.51	0.56
AB English		0.59	0.58	0.45	0.53
BS Biology		0.57	0.53	0.49	0.52
BSpecial Education		0.56	0.56	0.44	0.51
B Secondary Education		0.57	0.52	0.44	0.5
AB Political Science		0.56	0.49	0.43	0.48
BS Applied Mathematics		0.54	0.55	0.40	0.48
BS Information System		0.54	0.52	0.42	0.48
B Elementary Education		0.55	0.51	0.41	0.47
B Tourism		0.53	0.51	0.38	0.46
B Hotel & Restaurant Management		0.50	0.48	0.40	0.45
B Cooperative Management		0.56	0.46	0.36	0.44
B Broadcasting		0.50	0.46	0.36	0.42
B Journalism		0.48	0.44	0.38	0.42
B Music Education		0.47	0.43	0.32	0.39
BS Developmental Communication		0.41	0.42	0.3	0.36
B Physical Education		0.41	0.4	0.31	0.36
Total	Mean	0.55	0.51	0.42	0.48
n=1000	SD	0.19	0.16	0.16	0.14

Note: <0.50 = <50% = Least Learned; 0.50 to 0.749 = 50% to 74.9% = Nearly Mastered; ≥0.75 = ≥75% = Mastered

On the other hand, students of BS Nursing, BS Info Tech, AB English, BS Biology, B Special Education, B Secondary Education, AB Pol Science, BS Applied Math, BS Info Systems, B Elem Education and B Tourism have Nearly Mastered the domain. The higher order domain of reasoning and analysis is Nearly Mastered by BS Nursing and BS Info Technology students while students of all other programs have Least Learned this domain. Thus, the inquiry-based instruction can be implemented in these classes with some limitations.

In the Philippines, no standard or minimum requirement is set either for teachers' or students' preparations for the effective implementation of inquiry in the classroom. Department of Education (DepEd) recommended the use of inquiry-based instruction but has not established prerequisites for its effective use. In the United States, the National Research Council's (1996) science education standards list abilities that elementary students need to engage effectively in inquiry. For K-4, students should be able to ask a question about objects, organisms, and events in the environment. They should be able to plan and conduct a simple investigation, employ simple equipment and tools to gather data, and extend the senses. Moreover, they should be able to use data to construct a reasonable explanation, and communicate investigations and explanations. For grades 5-8, students should be able to identify questions that can be answered through scientific investigation, design and conduct a scientific investigation, use appropriate tools and techniques to gather, analyze, and interpret data. The students use evidence to develop descriptions, explanations, predictions and models, think critically and logically to relate evidence and explanations, recognize and analyze alternative explanations and predictions. Above all, they are able to communicate scientific procedures and explanations; and use mathematics in all aspect of scientific inquiry (Allen, 2006).

Based on the description of reasoning and analysis domain, grades 5-8 students should be well-grounded on this domain to comply with the requisite competencies to engage in inquiry. However, the results indicate that many high school graduates who enrolled in the university do not have the necessary skills for them to effectively engage in inquiry. Some Science items in the WVSU-College Admission Test involved inquiry skills. If science teachers have to implement classroom inquiry, it should be designed with the assumption that students are least prepared to engage in inquiry instruction appropriate for their age. But for groups who have attained better mastery of the science cognitive skills, they will benefit more from properly prepared inquiry instruction specially the development of higher order thinking skills.

Results of the correlation analysis of the students' scores (Table 5) in the different science areas included in the test, the nature of science, earth and space science, life science, chemistry, and physics are significantly and positively associated with each other. This indicates that students with high scores in any science subarea have also high scores in other subareas, and conversely.

Table 5

Correlation among WVSU-CAT Science Subarea Scores of Freshmen

Subareas in Science test	Correlation coefficient	p-value
Nature of Science and Earth & Space Science	0.323*	0.000
and Life Science	0.347*	0.000
and Chemistry	0.366*	0.000
and Physics	0.331*	0.000
Earth & Space Science and Life Science	0.393*	0.000
and Chemistry	0.433*	0.000
and Physics	0.368*	0.000
Life Science and Chemistry	0.358*	0.000
and Physics	0.345*	0.000
Chemistry and Physics	0.398*	0.000

Note: *$p < .05$.

Association of the students' scores in the different science cognitive domains is shown in the correlation analysis results in Table 6. Similar to science areas, scores in science cognitive domains are significantly and positively associated with others indicating that high scores in one domain are associated with high scores in other cognitive domains. For groups with low means, students are less likely to be college ready in all other aspects of science; hence, teachers have to re-teach high school science topics appropriate for the science subjects enrolled by freshman students.

Table 6

Correlation among WVSU-CAT Science Scores of Freshmen in the Science Cognitive Domains

Science cognitive domains	Correlation coefficient	*p*-value
Factual knowledge and Conceptual understanding	0.530*	0.000
Factual knowledge and Reasoning & Analysis	0.534*	0.000
Conceptual understanding and Reasoning & Analysis	0.535*	0.000

Note: *$p < .05$.

Conclusions and Recommendations

This study discusses science readiness of college freshmen and its potential implication on the use of inquiry-based instruction. Results showed that the group has Mastered the knowledge domain of Physics only while the other subareas by science cognitive domain were either Least Learned or Nearly Mastered at most. The group performed least in Life Sciences and then, Chemistry. Lower scores in subjects offered in the early high school years may be attributed to poor memory retention of students. Students of health, Science, and technology-related programs appear to have relatively higher ratings in the different areas in Science and the different cognitive domains compared to those in the non-Science programs. Subareas in Science are positively associated with each other. The same pattern is observed in the different cognitive domains hence weakness in one means weakness in other subjects. A group that exhibits strength in one area or domain, with high probability, will also display strong academic background in other areas. Associating the results with the students' readiness for inquiry-based Science instruction, teachers can comfortably employ inquiry in the classroom for groups who have at least nearly mastered the different areas in Science. Prior knowledge and skills in high school science may support readiness for college science performance. However, they have to employ caution when engaging in inquiry for those who have not attained the basic competency level for secondary Science. While this pedagogical approach is highly recommended to develop critical, logical, and creative thinking among students, it requires Science skills for it to be effective particularly the higher-order domain reasoning and analysis.

References

Achieve and the Education Trust. (2008). *Making college and career readiness the mission for high schools: A guide for State policy makers*. Retrieved from http://www.achieve.org/files/MakingCollegeandCareerReadinesstheMissionforHighSchool.pdf

Achieve, Inc. (2013). *Next generation science standards*. Retrieved from http://www.next genscience.org

ACT. (2008). *Connecting college readiness standards to the classroom: For science teachers*. Iowa City, IA: ACT, Inc. Retrieved from http://www.physicsclassroom.com/getattachment/reasoning/crs/ACT_Science.pdf

ACT and Council for Opportunity in Education. (2014). *The condition of college and career readiness 2014: First generation students*. Retrieved from http://equityinlearning.act.org/wp-content/uploads/2016/06/2014-first-generation.pdf

ACT (2015). *The condition of college and career readiness 2015*. Retrieved from https://www.act.org/content/dam/act/unsecured/documents/CCCR15-NationalReadinessRpt.pdf

Allen, R. (2006). *Priorities in practice: The essentials of science, grades K-6: Effective curriculum, instruction and assessment*. Alexandria, Virginia USA: Association for Supervision and Curriculum Development

Exline, J. (2004). *What is inquiry-based learning?* Retrieved from http://www.thirteen.org/ edonline/ concept2class/inquiry/index.html

Fang, Z., Lamme, L. & Pringle, R. (2010). *Language and literacy in inquiry-based science classroom, grades 3-8*. California: Corwin, A Sage Company.

Jarrett, D. (1997). *Inquiry strategies for science and mathematics learning: It's just good teaching*. Portland, Oregon: Northwest Regional Educational Library

Mullis, I., Martin, M., Smith, T., Garden, R., Gregory, K., Gonzalez, E., Chrostowski, S., & O'Connor, K. (2003) *Trends in mathematics and science study: Assessment framework and specifications 2003* (2nd ed). Chesnut Hill, MA United States: The International Evaluation of Educational Achievement, International Study Center, Lynch School of Education, Boston College.

Nagaoka, J., Farrington, C., Roderick, M. Allensworth, E., Keyes, T., Johnson, D., & Beechum, N. (2013). *Readiness for college: The role of noncognitive factors and context*. Annenberg Institute for School Reform.

Next Generation Science Standards. (2013). *Appendix C– a draft definition of college and career readiness in science*. Retrieved from http://docplayer.net/11304 525-Appendix-c-a-draft-definition-of-college-and-career-readiness-in-science.html

National Research Council. (1996). *National science education standards*. Retrieved from http://www.nap.edu/catalog/4962/national-science-education-standards

Wenning, C. (2005) Implementing inquiry-based instruction in the science classroom: A new model for solving the improvement-of-practice problem. *Journal of Physics Teacher Education Online*, *2*(4), 9-15.

Willoughby, J. (2005) Using inquiry in science instruction. *Teaching Today, Glencoe Online*. Retrieved from www.glencoe.com/sec/teachingtoday/subject/using_inquiry _sci.phtml

Zhang, M. & Li, X. (2007). Inquiry-based science instruction: An effective model for professional development. *The Charter Schools Resource Journal*, *3*, 31-49.