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Building Scientific Thinking through Inquiry - Designed Research and Practice in School Libraries

Jen R. Spisak
Longwood University, Farmville, VA, United States.
E-mail address: spisakjr@longwood.edu

Karla B. Collins
Longwood University, Farmville, VA, United States.
E-mail address: collinskb@longwood.edu

Abstract:

The AASL National Standards for Learners, School Librarians, and School Libraries (2018) strongly emphasizes inquiry and the inquiry process. The Next Generation Science Standards (NGSS) (National Research Council, 2013) describes scientific thought as four-fold: wondering, investigating, questioning, data collecting and analyzing. School librarians use multimedia methods to directly teach students to use the inquiry process to think scientifically. Students learn to initiate scientific research by formulating questions based on prior knowledge and curiosity. Students engage in the inquiry process by first developing questions then searching for and using evidence to investigate their questions. They learn to interact with the content they and others find to further their own and each other's knowledge, and they learn to continue questioning and building on the new knowledge they attain. When students fail to find the answers to their questions in the first place they look, they learn resilience.

School librarians promote the use of trusted subscription databases and teach how to effectively search using Google Scholar. And in school library instruction, students learn to use information resources from governments, historical societies, and museums. Student-conducted scientific research is benefited by using multimedia resources such as videos, podcasts, device apps, websites, and maker activities as well as school librarian created digital curations of scientific resources. In using multimedia resources, makerspaces, and advanced levels of curation techniques, school libraries are leading the charge in scientific inquiry and investigation.

Keywords: inquiry process, school libraries, scientific thought, multimedia resources, makerspaces, curation

What is scientific thinking?

Today's learners have unique strategies for learning; it is imperative that they are given the opportunity to develop scientific thinking using techniques that work for them. It is no longer enough to learn science concepts separate from doing science activities. In order to be prepared for 21st-century careers and citizenship, today's learners need to experience the integration of science and engineering and be able to see their connections to the larger world (National Research Council, 2013).

In 2013, the *Next Generation Science Standards (NGSS)* were developed to update state science standards based on current research related to science education. (*NGSS* can be found at this link: https://www.nextgenscience.org/standards-background-research-and-reports) *NGSS* align with English and Math Common Core Standards that are followed by the majority of states in the United States of America. The *NGSS* stress the importance of pairing science content with practice instead of teaching content separately. In this manner, science knowledge is learned through active participation in science activities. Additionally, engineering concepts are given equal weight to scientific inquiry (National Research Council, 2013).

The flexible nature of the *NGSS* fits nicely into the school library goals of encouraging critical thinking and exploration. Through collaboration with classroom teachers and through school library instruction and programming, school librarians foster scientific thinking. School librarians are equipped with the skills and tools to create environments that address the needs of current learners. Science knowledge is designed to be taught progressively through the grades, providing time and experiences which will allow the students to apply their scientific knowledge and develop deeper scientific thinking (National Research Council, 2013).

NGSS describes scientific thought as four-fold: wondering, investigating, questioning, data collecting and analyzing. Further, *NGSS* states eight basic understandings of the nature of science:

- Scientific Investigations Use a Variety of Methods
- Scientific Knowledge is Based on Empirical Evidence
- Scientific Knowledge is Open to Revision in Light of New Evidence
- Scientific Models, Laws, Mechanisms, and Theories Explain Natural Phenomena
- Science is a Way of Knowing
- Scientific Knowledge Assumes an Order and Consistency in Natural Systems
- Science is a Human Endeavor
- Science Addresses Questions About the Natural and Material World (National Research Council, 2013, Appendix H)

Knowing the basis behind scientific thought and the nature of science guides the school librarian in creating learning opportunities which allow students to think scientifically in the school library.

Inquiry

In 2018, the American Association of School Librarians (AASL) released its most recent iteration of standards titled *National School Library Standards for Learners, School Librarians, and School Libraries*. Inquire is a Shared Foundation within these standards that encourages curiosity and questioning. Using an inquiry process, learners think about their topic, develop questions, gather information, think critically about the information found, make decisions based on prior knowledge and

the answers to their questions, share information, and reflect on their process. In essence, learners use the inquiry process to think scientifically by wondering, investigating, questioning, and collecting and analyzing data. There is a natural connection between the inquiry process used in school libraries and the *NGSS* definition of scientific thought.

The inquiry process has larger meaning in scientific thinking and research. Inquiry has become the go-to method for organizing research in schools. Students are expected to generate questions about topics of interest and develop a plan for finding the answers to their questions. Creative thinking is encouraged and expected. However, this is a skill that must be taught. Today's students are curious, but tend to be hesitant to trust their own creative processes without encouragement. They tend to worry that the questions they ask won't be the right questions. The school librarian plays an important role in encouraging creative inquiry and exploration by designing instruction and experiences in the library that support students' creativity (Coatney & Harada, 2017).

Without the constraints of a curriculum- and testing-centered classroom, the school library is a space where students are free to experiment and test their individual ideas in a safe environment (Coatney & Harada, 2017). It is a space where they are allowed to make multiple attempts to solve a problem before finding success. Failure through honest effort is lauded as a learning experience rather than treated as a reprimandable act. Students learn that the term ***RE****search* is aptly named and that resilience in the face of difficulty is valuable. Creative expression is encouraged, supported, and celebrated in today's school library.

In inquiry-driven research in the school library, students explore multiple modes of media resources. They learn to use trusted subscription databases and effectively search using Google Scholar while also acknowledging that the information they find may not always match their purpose. Through this process, they learn that research is iterative and that they need to use information sources beyond general online Google searches and/or their favorite subscription database.

Science and Technology Multimedia Resources

The definitions of "literacy" seem to grow almost daily. Likewise, the idea of "digital literacy" must evolve as new technologies are introduced. Students must have a knowledge of the vast range of digital resources and ability to navigate the digital world. This is best taught through opportunities to experience various digital tools and applications (Lowenthal, Dunlap, & Stitson, 2016). As educators, school librarians have a responsibility to model and teach ethical use of digital resources. It is important to assist students in their understanding of their own digital footprint.

A variety of resources are available to school librarians where quality multimedia information can be found. Through exploration of these online resources, students broaden their scientific thinking about the world and their place in society. They learn to use information from governments, historical societies, and museums. They learn the benefits of videos, podcasts, device apps, websites, curation, and maker activities.

A study by Barnyak and McNelly (2015) found a positively significant difference in students' retelling of both print and electronic nonfiction books when teachers were directly involved in the learning as compared to when they were not. This study did not find a statistically significant difference between students' retelling experiences when comparing print to electronic books regardless of teacher interaction. These findings support the importance of having a school librarian available to guide the instructional experiences of students with digital and print resources. Not only should a variety of resources be available (print and electronic), but an educator should also be available to aid in the educational experience. Students learn in different ways and the provision of a variety of multimedia resources can assist school librarians in meeting the individual learning needs of all students.

Some examples of the multitude of ways students are interacting, learning about, and exploring scientific research in school libraries are as follows. Students learn to code using websites and self-

programming robots, examine the human body using augmented reality programs, explore the ocean using virtual reality applications, grow plants building their own plant-growing hydroponic apparatus, determine typography using Google maps, interact with an astronaut through Skype, and make abstract concepts more concrete through 3D printing. They watch video clips on elephant seismology and use online simulators to learn how changes in force and motion can alter wavelength, amplitude, and frequency (Eckels & Soash, 2018). They participate in virtual labs and interactive videos from online science resources such as *BioInteractive* and *Science Friday* to learn about a multitude of science topics such as natural selection and adaptation and even how people get their skin color. These are just a few of the many examples of what is occurring with multimedia resources for science research and investigation in school libraries.

Makerspaces

Makerspaces are exactly what the name implies – spaces to make (Moorefield-Lang, 2018). "The maker movement encourages tinkering, thinking, problem solving, collaboration, innovation, and creation" (Seymour, 2018). Makerspaces tend to focus on Science, Technology, Engineering, and Math (STEM) initiatives and encourage learners to think creatively and innovatively to explore their world using various tools and materials. Seymour (2018) encourages learners to take this thinking process a step further and use makerspace materials to address a problem in society and offer solutions to that problem. Makerspaces aid in encouraging learning by providing opportunities to be hands-on with tools and materials that help learners develop their thinking. The combination of learning and doing is the essence of the makerspace movement (Hamilton & Schmidt, 2014). As Hamilton and Schmidt state, the "mission of the library is to support self-education" and exploration through a makerspace can be an ideal opportunity for this. They emphasize the importance of a makerspace that allows learners not only to experience and acquire new knowledge but also to share that knowledge with the community of learners. In this definition, makerspaces contribute to the human endeavor of scientific thinking as identified by *NGSS*.

Makerspaces take on many forms, and no two makerspaces are or should be alike (Moorefield-Lang, 2015). School librarians develop a library makerspace to meet the needs of the learners in their building. This might mean that the makerspace is portable to travel to classrooms in support of instruction or that the librarian and teacher work collaboratively to bring students into the library to use the makerspace at the point of need. Materials in the makerspace might vary in focus depending on the needs and abilities of the learners, teachers, and school librarian. Some common resources and materials found in a school library makerspace include robotics, 3D printers, sewing machines, woodworking/burning Dremel machines, broken electronics to be rebuilt or disassembled, Ozobots and Spheros, circuitry kits, and Makey Makey kits. You'll also see non-electronic materials such as Legos, crafting supplies, Duct tape, puzzles and games, and Keva planks. You will see students in makerspaces with classes for projects and/or experiential learning, students on their own exploring topics that interest them personally, or even groups of students constructing things in a makerspace for service learning projects (Seymour, 2018). Whether the materials students use are electronic or not, or whether the purpose is whole-class instruction, independent learning, or group-based service learning, the maker movement is an ideal example of school library focus on scientific thinking and learning.

Curation

In addition to the student inquiry driven uses of the multimedia resources and makerspaces mentioned previously, school librarians are using digital curation techniques to provide students with relevant resources that are constantly being updated. Traditionally, a main role of a school librarian was to gather and organize information so it is accessible for library users. This traditional role is the essence of curation, although the scope of information has greatly increased. Curation of science resources for students and teachers is an important way school librarians are providing support to science education. School librarians are challenged to provide quality resources to teachers before the teachers feel the need to search for their own resources (Collins & Doll, 2012). In many schools where librarian positions have been eliminated, teachers do not have the luxury of having a skilled curator of

resources in their midst (Mardis, 2015). Even in schools with school librarians, it is easy for teachers to feel they are able to search for and locate information without the assistance of the librarian. However, school librarians as curators are able to ensure that quality resources are provided that meet the immediate needs of the students and teachers in their building (Mardis, 2015). Through effective curation, school librarians are able to manage the information that is presented to the students to ensure students have the best opportunity to inquire and discover through rich, relevant resources.

Joyce Valenza identifies collection development tasks as "scouting, identifying relevance, evaluating, classifying, organizing, and presenting aggregated content for a targeted audience" (2012). Today's collection development and curation go beyond only commercially available and purchased materials (Valenza, 2017), which is important to remember when curating resources that support scientific thinking and experiences. Curated science resources might include an online curation of websites and/or tools, Open Educational Resources (OER), professional development and online learning opportunities for teachers and students, and student- or teacher-generated materials in addition to more traditional print, audio-visual and digital resources. The science collection might also include manipulatives, tools, and materials to use in scientific and engineering activities, which partner well with school librarian created digital curations of resources and OER.

Carefully created digital curations often include currently updated US government websites such as National Aeronautics and Space Administration (NASA), National Institutes of Health (NIH), Environmental Protection Agency (EPA), the National Air & Space Museum, and the National Science Foundation as well as state and local science museums and college and university laboratories which are curated for students and posted in collections or on school websites. Scientific Open Educational Resources (OER) such as the National Science Digital Library (NSDL), PhET for interactive science simulations and games, MIT Blossoms for science lessons and videos, Khan Academy, and PBS abound. These methods of curation are crucial in scientific instruction, research, inquiry, and investigation.

Sharing with Others

The instructional role of the school librarian does not stop at instruction for students; the entire school community are potential learners for school library instruction. This includes teachers, administrators, and parents as well as other school librarians and educators beyond the walls of the school library (AASL, 2018). Librarians are uniquely situated to see the bigger picture of what is being taught throughout the school (Collins & Doll, 2012). Therefore, professional development opportunities can be offered at the point of need and focus on resources that will aid teachers in improving instruction for students. School librarians can provide professional development sessions where teachers explore science-related resources and tools and apply the use of those tools to their classroom instruction. Regular professional development opportunities by the school librarian provide the teachers with continued growth as they learn about new tools and how to apply them to their instruction (Coatney & Harada, 2017). Additionally, teachers can experience how collaboration with the school librarian will enhance instruction by greater use of resources and more opportunities for individualized instruction.

School librarians can also share science and engineering resources with other librarians at library conferences. To further the reach of the librarian, similar information about the importance of working with the school librarian to improve science instruction should be shared with educators in other disciplines. Educators outside of the library often do not know what happens within the library. School librarian presentations at other conferences, namely science and technology conferences, allow the reach of the librarian to go beyond just the library world.

Conclusion

School librarians, along with science teachers, are the first people young learners encounter that teach them to think scientifically. They use various creative methods to do this, including using multimedia resources, curation techniques, and makerspaces. School librarians scaffold instruction by age and begin

instilling the inquiry process by showing students the power of curiosity and questioning. Students learn to become resilient as they discover that learning is an iterative process involving trial and error. Through these methods, students learn the value of thinking scientifically and using the inquiry process. They learn that process matters in the quest for information and ultimately knowledge.

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