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Article

Cultivating a science literate society: Academic librarians' role and approach for promoting science literacy in undergraduate students

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Abstract

This paper explores the critical role librarians play in promoting science literacy among undergraduate students. By examining the interconnected nature of information literacy, science literacy, and digital literacy in today's digital landscape, this paper addresses the unique information needs of students and the implications of supporting them in becoming science-literate citizens. As information literacy instructors, librarians are essential facilitators of knowledge and learning in academic contexts. Practical recommendations are provided for librarians to design and deliver effective science literacy instruction.

Keywords: information literacy, science literacy, library instruction, undergraduate students

Introduction

Scientific knowledge has endless potential to better the life of all individuals and communities. Knowing how to appropriately interact with scientific information is important for all citizens, as not only does science penetrate all aspects of everyday life but is also necessary for making informed decisions and engaging in critical thinking (Griffin & Ramachandran, 2010; Lee & Tamar, 2021). As librarians, it is part of our responsibility to promote information access and literacy, "including the ability to identify, locate, evaluate, organize and create, use and communicate information" (CFLA-FCAB, 2018). In working to ensure access to information, we are helping to shape individuals who can be informed participants in society and promoting the ethical use of information (CFLA-FCAB, 2018).

In this paper, I will begin by introducing the concepts of information literacy, science literacy, and digital literacy, as well as the need to view these literacies as an overlapping, joint entity. Next, I will discuss the information needs of undergraduate students and science literate citizens. Lastly, I will explore some examples of how literacy instruction (specifically regarding scientific knowledge) can occur, followed by recommendations for librarians about how to best approach science literacy instruction.

The different literacies: Information, science, digital

Information literacy

Information literacy is the "skills required to find, evaluate, and use information thoughtfully and appropriately" (Lee & Tamar, 2021). In a 2008 UNESCO report, Catts and Lau (2008) break down information literacy to include: (1) recognizing information needs, (2) locating and evaluating information quality, (3) storing and retrieving information, (4) effectively and ethically using information, and (5) applying information to communicate knowledge (Lee & So, 2014).

Science literacy

Science literacy is a type of information literacy, with most definitions focusing on "basic conceptual knowledge, principles of scientific inquiry, and the role of science in everyday life" (Majetic & Pellegrino, 2014, p. 107). In their definitions, Science Literacy Foundation (SLF) and the American Association for the Advancement of Science (AAAS) both emphasize the understanding of science knowledge as dynamic, with the potential to be applied for and improving individual and social purposes (AAAS via Liem, 2005; SLF, 2021).

Howell and Brossard (2021) further note that science literacy should account for the entirety of the science-information lifecycle: including how scientific knowledge is generated, how it is reported through media channels, and how people interact with it on an individual basis. They emphasize that in becoming science literate, individuals will "feel equipped to access and use trustworthy science-related information when needed for informed decision-making" (Howell & Brossard, 2021, p. 2).

Digital literacy

Canada's Centre for Digital Media Literacy (CCDML) defines digital literacy as "the ability to critically, effectively and responsibly access, use, understand and engage with media of all kinds" (CCDML, n.d.). Much like in information literacy, there is an emphasis on critically engaging with information in the media, focusing on access, analysis, and use (Lee & So, 2014).

The overlap between literacies

Although there are various types of literacies defined across the field of information science, the boundaries between them are often uncertain. Especially in today's rapidly changing society, people must be equipped with a set of widely ranging skills to navigate constant information overload. Moving away from viewing the literacies as separate entities is a necessary step towards equipping individuals with the tools necessary to fully engage with generating, sharing, and applying knowledge (Lee & So, 2014). Specifically, exploring the overlap between information literacy, science literacy, and digital literacy will help librarians better teach literacy with an approach that meets the needs of undergraduate students.

When exploring the concept of information literacy in their study, Witherspoon, Taber, and Goudreau (2022) had one responding faculty member state: "I can't think of anything you can do in the world today that you can do without this… [There is] no task that doesn't involve information. Every person in the world today at every level needs it" (p. 297). Information literacy is ingrained within the scientific process itself, as without the skills to first find and evaluate credible scientific information, students cannot be expected to effectively navigate scientific knowledge (Klucevsek, 2017).

Science literacy and digital literacy specifically are vital in successfully navigating the modern world, as science and digital media are interwoven into all aspects of everyday life (Griffin & Ramachandran, 2010). An aspect of science literacy that has emerged over more recent years is the need to navigate information from a variety of information sources, especially as misinformation and non-credible sources filter through (Howell & Brossard, 2021). Howell and Brossard (2021) call this 'digital media science literacy', consisting of: (1) accessing science information online, (2) understanding how science information moves through online environments, and (3) evaluating science information being shared by the media.

A quote by Shortland (1988), as cited by Griffin and Ramachandran (2010), summarizes the need for a mindset shift: "In a word, to become scientifically literate is to become an effective citizen'" (p. 326). It is necessary to promote developing comprehensive skills for interacting with both science and information (i.e., science literacy and information literacy) in a modern world (i.e., digital literacy). As information literacy instructors, librarians play an integral role in teaching students that science is an "essential tool in their social and community toolbox" (Majetic & Pellegrino, 2014; SLF, 2021), acknowledging the added layer of digital media and technology ensures that students develop an understanding of how information is disseminated in the current world (Howell & Brossard, 2021; Lee & Tamar, 2021). Achieving true science literacy, therefore, depends on many factors and goes beyond simply learning about the scientific process; it involves linking the processes of information literacy with critical thinking skills, knowledge about both science and the research process, and understanding of how information is communicated in the digital age. The following sections will take a closer look at how librarians can create opportunities for effective science literacy instruction in response to students' information needs, contributing to shaping the next generation of science-literate citizens.

Setting the scene

It is important to note that few librarians who are responsible for providing information literacy instruction *within* the sciences have a background *in* the sciences (Witherspoon, Taber, & Goudreau, 2022). A 2018 survey put out by the Canadian Association of Professional Academic Librarians (CAPAL) revealed that out of the 346 master's degrees held by respondents, only 16 were in the natural sciences (CAPAL, 2018; Witherspoon, Taber, & Goudreau, 2022). By establishing an understanding of the information needs and behaviours of undergraduate students, librarians (regardless of their own background) will be better equipped to provide information literacy instructions.

Information Needs of Undergraduate Students

The specific information needs of undergraduate students are not well-researched, especially within the sciences, a gap that Witherspoon, Taber, and Goudreau (2022) aimed to fill by speaking with undergraduate instructors and faculty. Study respondents agreed that during the second and third years of undergraduate studies, there should be a focus on training for beginning to build research skills, including advanced database searching and narrowing research results (Witherspoon, Taber, & Goudreau, 2022). These skills are important to introduce early, as studies have identified that undergraduate students struggle with starting their research process, often favouring Google rather than turning to sources like library databases (Head, 2017 via Witherspoon, Taber, & Goudreau, 2022). Further, in their early undergraduate years, science students should not be expected to interact with peer-reviewed research in their fields, but instead focus on more digestible sources like reviews, textbooks, 'easy' journals, blogs, forums, and popular science writing (Witherspoon, Taber, & Goudreau, 2022). The expectation of understanding and working with peer-reviewed research begins to emerge in fourth year, but often not fully until graduate studies (Witherspoon, Taber, & Goudreau, 2022).

Science and the current world

Howell and Brossard (2021) note that: "it is crucial to think of science-literate citizens … in ways that account for the realities of our modern, digital world, across the lifespan of scientific information as people access and act on it" (p. 7). With the rise of technology comes increasingly easy access to information; Google and the Internet allow individuals to find a plethora of knowledge, from textbooks and articles to social media and news releases. This ease of access and variety of formats makes it easy to take for granted that the scientists who are originally conducting their research are doing so based on extensive study and training, with a specialized skill set for both interpreting and sharing their findings (Alcoreza, 2021). This skill set is not developed to the same extent in those individuals who are conducting knowledge translation (like journalists), and even less so in the individuals consuming this information. Therefore, the way science is communicated in the common world, when done irresponsibly, can be misleading and harmful (Alcoreza, 2021). Howell and Brossard (2021) identify that this misinformation most often takes the form of three possible categories: (1) misinformation about what a scientific study does answer, (2) misinformation about what scientific research can answer, and (3) misinformation about the ease and speed of the scientific process.

When science educators are teaching students, there is often emphasis placed on theory, research methods, and problem solving (SLF, 2021). In undergraduate studies, this learning begins in introductory science courses during first year, with large class sizes and a mix of science major and non-major students. However, these introductory courses often prioritize covering content, leaving little room to promote science literacy itself (Reynolds & Ahern-Dodson, 2010). As librarians are trained to interact with the entire lifecycle of information, it is librarians who are the most likely sources of information literacy education and are responsible for teaching a set of skills that move beyond the "model of fact-and-formula memorization plus standardized testing" prevalent in classrooms (SLF, 2021). Literacy relies on critical thinking (including skills in logic and identifying bias), which is crucial to foster in students to help them learn to identify misinformation and understand how personal factors might also impact how they acquire and analyze the information they interact with (Lenker, 2016 via Klucevsek, 2017; SLF, 2021).

Science literacy in practice

Across the fields of information science, library studies, and pedagogy, there are plenty of theoretical and practical explorations of how literacy can be approached. This section will introduce science literacy instruction specifically, taking a closer look at a number of interesting methods to consider that move beyond classroom-based learning.

Learning approaches rooted in curriculum

Research-service learning
Reynolds and Ahern-Dodson (2010) describe research-service learning (RSL), which is based on the pedagogy of student engagement in service-learning contexts. When developing an RSL-based course, instructors should ask "what do students need to learn to achieve the course goals?"; this ensures that information literacy is incorporated into the course foundation (Reynolds & Ahern-Dodson, 2010, p. 25). Students are encouraged to develop research questions which are relevant to their communities. This approach promotes science literacy by not only teaching students how to use scientific knowledge and understand the strengths and limitations of the scientific process, but how to apply it in real-world contexts relevant to themselves (Reynolds & Ahern-Dodson, 2010).

Integrated science programs
The Integrated Science Program (developed with the involvement of a librarian) discussed by Yu (2017) is offered at McMaster University and has science literacy instruction fully integrated into the curriculum. The program teaches essential knowledge and skills relating to the scientific disciplines while prioritizing self-directed, inquiry-based, and project-oriented learning (Yu, 2017). Librarian involvement can take the form of formal information literacy sessions or providing learning space for students but, overall, acts to help students understand how information forms the basis of effective scientific discovery and communication (Colgoni & Eyles, 2010; Yu, 2017).

Learning approaches rooted in hands-on activities

Reflection through bad science
Yu (2017) discusses an approach derived from Ben Goldacre's column in The Guardian, Bad Science. The basis of this activity centers around having students evaluate examples of 'bad' science, which creatively engages them in reflection on the scientific publication cycle (Yu, 2017). After almost a decade of scientific research, writing, and education, Goldacre posits that looking at 'bad' science is the easiest way to understand how 'good' science works (Goldacre, 2011; Yu, 2017).

Reading a scientific paper
In this exercise described by Majetic and Pellegrino (2014) (professor and librarian at St. Mary's College, respectively), students are assigned a short scientific paper relevant to the topic currently being covered in their class, and are provided with a list of questions which guides them through reading the paper section-by-section (see Figure 1).

Figure 1
Questions assigned to support in-class discussion of assigned scientific paper from Majetic and Pellegrino (2014).

TABLE 2
Questions Assigned to Support In-Class Discussion of Assigned Scientific Paper

Question 1	Look at the Abstract at the very beginning of the paper—what is the point of this paragraph?
Question 2	Flip to the Discussion and look at the first two paragraphs, which usually summarize the most important points of the paper. What do these authors say are the most important things you should take away from this paper? Does this match up with what the Abstract says?
Question 3	Take a look at the figures and tables in the Results section. Can you describe what these tell the reader? Does the text in the Results section match the contents of the figures and tables?
Question 4	The first section of the paper is the Introduction, which usually describes the background information that the authors use to frame their research. The last few paragraphs in the Introduction usually outline the questions or hypotheses that the researchers intend to answer in the paper, and why. Can you summarize these things in your own words? Do your findings match what the Discussion and the Abstract say?
Question 5	Finally, take a look at the Methods section. This is usually the most technical section of the paper. Are there any ideas in this section that make sense to you? Any ideas that do not? Come with any questions that you might have.

Rather than requiring students to grasp the article's scientific content, this approach encourages students to focus on research goals and findings, while considering the types of details and sections that might be important (Majetic & Pellegrino, 2014).

This is followed by two discussion periods: the first in small student groups focused on discussing the provided questions, and the second a full-class, instructor-led discussion about the article's content. In this second session, the instructor helps students interpret tables, figures, graphs, and images as well as written content (Majetic & Pellegrino, 2014). At the end of the discussion period, students are tasked with writing a 2-3-page synopsis evaluating the paper's use of the scientific method, as well as their opinion on whether or not the paper achieved its objectives successfully (Majetic & Pellegrino, 2014).

New story assignment
The first part of this activity is a library instruction session where students are taught the skills for: (1) finding the original research referenced in a news article, and (2) finding a second, related scientific paper to complement the original (Majetic & Pellegrino, 2014). The librarian demonstrates using tools like Google Scholar to find uncited research, as well as teaching students how to access online materials via the library's online journal subscriptions or interlibrary loan system (Majetic & Pellegrino, 2014). Additionally, the librarian provides an overview of using library databases to find further research on the given topic. Students are given time to work on the two tasks during the instruction session, with both the librarian and course instructor available to provide support. After the library instruction session, students write a synopsis about the assigned news story and their scientific papers. This gives them the opportunity to reflect on the research process, as well as the difference between professionally published science and non-specialist sources.

Learning approaches rooted in external knowledge sources

Science Cafes
Science Cafes are sessions held in informal settings, such as cafes, restaurants, or other public places, where the public has an opportunity to engage in conversations with scientists[1] (Powell, 2010 via Yu, 2017). The scientific and technological topics are wide-ranging and will depend on the knowledge of the invited guests, but the local context of where the Cafe is taking place is considered (Yu, 2017). The goal is to facilitate dialogue between scientists and non-scientists about science and technology, with scientists making the topics more approachable by using plain language and encouraging discussion (Powell, 2010 via Yu, 2017).

The Science Adventure Centre
The Science Adventure Centre[2] is part of the Bishop Museum in Honolulu, Hawaii and is dedicated to increasing science literacy by relying on large-scale, multi-sensory displays to immerse visitors within the world of science (Liem, 2005). For example, the Hot Spot Theater embraces the fact that the amount of engagement is positively related to the number and degree of senses being stimulated:

> [...] A furnace used to melt lava rock creates a literal hot spot that visitors can feel from the other end of the room, while ceiling panels with a rippled texture and moving red lights create the impression of standing inside a volcano. (Liem, 2005, p. 2075)

This concept can be traced back to primary school classrooms, with colourful posters decorating the walls, to traditional methods of early education science teachers, where lessons are rich with visual, auditory, and/or tactile elements (Liem, 2005).

Recommendations for fostering science literacy in undergraduate students

Appeal to students' curiosity

Curiosity not only motivates individuals to seek information but helps promote lifelong learning, bridging the two territories of information literacy and science literacy (Yu, 2017). Yu (2017) discusses how genuine curiosity helps individuals connect with information and scientific research on a personal level, stimulating inquiry and interest. Additionally, curiosity fosters critical thinking and a mindset that helps students evaluate scientific information, rather than simply rely on what could be untrustworthy sources (SLF, 2021). Librarians can motivate curiosity in many creative ways, including through bringing in information forms like podcasts, current news, museums, and science centers, as well as appealing to students' sensory curiosity, from dynamic learning experiences to the use of sharp colours, clear fonts, and imagery (Liem, 2005; SLF, 2021).

Create a welcoming and low-pressure environment

Is the instruction session taking place in a library classroom or a large lecture hall? By creating a welcoming, low-pressure environment during sessions and meeting students in their comfort zones, the new skills and scientific knowledge being discussed will feel less intimidating, resulting in participants who will engage more readily (Majetic & Pellegrino, 2014; SLF 2021). If possible, it can be beneficial to

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[1] Science Cafes can be organized by anyone, including universities, local libraries, independent researchers, etc. Yu (2017) discusses this approach in the context of universities (i.e., Carleton University, University of Windsor) and government organizations (i.e., Canadian Institute of Health Research).
[2] To explore the creative experience offered by the Bishop Museum, see: www.gyroscopeinc.com/bishop

bring unfamiliar knowledge (in this case, science) into the world that undergraduates already know and are comfortable in (SLF, 2021). For example, residence common rooms, campus pubs, or other similar community spaces.

Beyond the physical space, this idea extends to the atmosphere of the session. In the 'Reading a Scientific Paper' example of achieving science literacy, Majetic and Pellegrino (2014) note that in the first discussion session students engage is deliberately in smaller, student-based groups. This setup "allows students to test out their answers safely among their peers before presenting them to a larger audience or the professor" (Majetic & Pellegrino, 2014, p. 109). Librarians can utilize smaller discussion groups (or smaller instruction sessions) to help participants feel comfortable, as well as rely on tactics like ice breaker activities to help students feel at ease.

Build on existing knowledge

Liem (2005) discusses constructivist learning theory, which posits that "new knowledge and understanding is built upon prior knowledge"; not only does an existing level of familiarity help engage an individual's attention but is also more likely to result in lasting change (p. 2076). Librarians can draw on existing knowledge to create new knowledge and can augment students' already established understandings of concepts and processes (Liem, 2005). The Science Adventure Centre, for instance, engages locals' knowledge by focusing on Hawaii's unique natural environment, incorporating "news stories about Kilauea volcano, the daily surf report, and even the rainbow decorating the state's license plates" into the educational exhibit (Liem, 2005, p. 2076).

In addition to building on existing knowledge, librarians can create instruction sessions that draw on existing issues that are important student communities. SLF (2021) states that in order to reach audiences, one has to "deliver the science related to problems or issues that people can unite around to solve, no matter what their politics." This approach includes an element of human-centered design, requiring librarians to place students at the center of the instruction process and focus on information that students have identified as important to themselves and their communities (Young, 2021). The human-centered design approach is also an important reminder for librarians to establish an understanding of their audience's skill set and level of literacy prior to designing and delivering an instruction session. This is a vital component of creating sessions which are appropriate and suitable to students' knowledge levels and skills.

Focus on developing basic skills

As uncovered by Witherspoon, Taber, and Gourdreau (2022) when speaking to various undergraduate instructors and faculty, much of an undergraduate degree (especially in second and third year) should be used as a time to connect with students and provide training to build basic research skills. This is an especially important aspect to keep in mind when teaching science literacy to non-science major students, who will benefit more from being taught things like how to find and evaluate sources rather than advanced scientific research skills (Majetic & Pellegrino, 2014). As such, it is beneficial to frame science literacy instruction as a "responsibility shared across a student's educational experience" (SLF, 2021), and librarians might consider developing mutual, collaborative relationships with science instructors in order to align their instruction sessions with both the information needs of undergraduates and the expectations of their instructors.

Incorporate practical tips

In addition to basic research skills, librarians should focus on highlighting practical tips that undergraduates can rely on to make their research process more straightforward and convenient. For example, the *Google Scholar for Research* online module developed by The New Literacies Alliance not only focuses on Google Scholar as an information tool but also walks students through the steps of linking Google Scholar with the school library account, which makes it easier to directly access scholarly papers.

Incorporate time for hands-on learning
Incorporating opportunities for hands-on learning during a session and leaving time for practice ensures that students are actively engaged in learning the skills they are being taught. It might be especially beneficial since the librarian (and maybe the course instructor) can be available to answer questions and help students overcome issues, as in the 'News Story Assignment' described by Majetic and Pellegrino (2014).

Connect students to the research community
As discussed in Yu's (2017) Science Cafe, facilitating informal discussions between scientists and non-scientists is a good way to foster science literacy. Librarians should feel encouraged to draw on the expertise of the research community in their institutions, inviting instructors and faculty to collaborate on developing instruction sessions or act as 'guest speakers', especially when a session is relying on real-world examples that are relevant to the researcher and the student community. Further, Yu (2017) suggests that academic libraries can organize special cafes that invite senior graduate students to attend, asking them to speak to the process of how they formulated and iterated their research questions. This would not only provide undergraduate student participants with the opportunity to learn about the research process in the 'real world' that is closer to them, but also develop a greater understanding of how to ask better questions (which is perhaps the most foundational skill that needs to be developed). Fostering this network will create communities who are connected and engaged with each other, as well as science literacy.

Move beyond scholarly, peer-reviewed materials
There are a multitude of scientific resources suitable for the needs of undergraduate students that are beyond the standard scholarly, peer-reviewed article. The undergraduate instructors and faculty respondents in Witherspoon, Taber, and Gourdeau's (2022) study refer to materials like reviews, popular science articles, and forums; teaching the skills required to locate these materials in academic databases. Librarians should develop instruction sessions that directly inform students about how they can find these more intellectually accessible materials, with an added emphasis on how to ensure that they are still relying on information from credible sources.

Be transparent and accurate about what science is like
Over the course of their entire education, most students are taught about the scientific method, which portrays scientific research as rigid and structured. In reality, science is an "iterative, imperfect, and flexible process of discovery that makes mistakes and then corrects itself over time" (SLF, 2021). Corey Powell, science journalist and co-founder of SLF, likens the process to a creative endeavour:

> You might wonder why a movie director decided to capture a scene a certain way, or why a songwriter wrote a specific lyric. "When you see a scientific paper, you can think about it the same way," he says. "Something very important motivated people to do this research. Who are these people? What are their possible motivations?" (via Young, 2021).

To ensure that science literacy skills are developed, librarians can help reshape and correct any misconceptions of what science is, how it works, and what it can answer.

In addition to this, there are systemic issues in both academic and popular spheres that are important to acknowledge so that students fully appreciate the risk of untrustworthy sources or skewed information. Young (2021) points out how "negative results are often less likely to be submitted by authors, accepted by journal editors, or received by the media than positive, significant findings." Librarians can draw on techniques like 'Reflection Through Bad Science', as described by Goldacre (2011) and Yu (2017): students must be taught that, even if they have mastered the skills innate to science literacy and feel confident in interacting with scientific work, they must remain vigilant about the credibility and bias that, without fail, exists within research.

Finally, it is important for librarians to confront the reality of bias and systemic inequalities that exist within the scientific world, even beyond publishing. They should reiterate their commitment to promoting the ethical and accurate use of information to confront culturally relevant material about inequities and discrimination (Pinedo et al., 2021; del Junco, 2024). This has been shown to increase the extent to which individuals in historically excluded groups (including women, Indigenous students, and students of colour) engage and identify with science knowledge (Pinedo et al., 2021; del Junco, 2024).

Final thoughts

As librarians, we are knowledge keepers - the bridge between information and society. Our role in fostering literacy, especially in university settings, places us in a unique position to teach undergraduate students the skills necessary to find, evaluate, and use information effectively. By actively promoting information literacy, science literacy, and digital literacy in response to both students' needs and an evolving society, we are enhancing their preparedness to be active participants in society who are equipped to use information accurately and ethically. This paper aims to offer librarians practical insight on how to address the information needs of undergraduate students while delivering effective, inclusive science literacy instruction.

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