Companion Document to the Framework for Information Literacy for Higher Education

Science, Technology, Engineering, and Mathematics

Approved by the ACRL Board of Directors, August 1, 2022

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Introduction

Goals and Objectives

Science, technology, engineering, and mathematics (STEM) disciplines require that students demonstrate information fluency not only in written research assignments and collaborative projects, but also in unique and complex information creation areas such as experimentation, computer modeling, design, and mechanical drawing visualizations. The objective of this document is to provide a framework that science, engineering, and technology librarians, their faculty collaborators, and other educational stakeholders can use and customize to align with local information-literacy-related instruction and assessment in an academic setting, as well as for lifelong learning.

Our goal is to create a learner-centered *Framework for Information Literacy* situated in the context of science and technology. This document exists in relationship to the general ACRL *Framework for Information Literacy*, while extending, adding, or contextualizing the frames, knowledge practices, and dispositions through a science lens. This includes the unique considerations required for advancing equity and justice in both the discipline of the sciences, as well as the local and global impact of the sciences. This *Framework* can be readily used by STEM educators to conceptualize information literacy in the disciplines, and by librarians and others to understand how information literacy might look in STEM fields. These groups will be able to use the Science and Technology *Framework* to tie information literacy into the context of their institution's mission, to help guide their information literacy-related instruction, to be incorporated in curricula, syllabi, and assignments, and to assess student progress at the undergraduate, graduate, and professional levels.

The STS *Framework:*

- Opens the way for librarians, faculty, and other institutional partners to redesign instruction sessions, assignments, courses, and curricula in the sciences.
- Assists STEM librarians to bridge their information literacy expertise to STEM faculty's disciplinary expertise
- Connects information literacy explicitly with STEM student success initiatives; - Informs collaboration on pedagogical research and involves students

themselves in that research in a disciplinary context.

- Helps create wider conversations about student information literacy learning, the scholarship of teaching and learning, and the assessment of learning on local campuses and beyond.
- Positions students to create new knowledge in their domain of expertise, and critically approach science and technology problems in daily life.

Key Terms

Novice & Expert - Used to describe the relative experience of Information Literacy learners (as opposed to disciplinary experience). Note that experts are still treated as learners.

Knowledge Practices - The Information Literacy learner learns these skills and understands these are ways to ideally operate (see also *Framework for Information Literacy for Higher Education*, Note 5, pg. 9).

Dispositions - The Information Literacy learner incorporates these things as routine habits (see also *Framework for Information Literacy for Higher Education*, Note 6, pg. 9).

Notes

1. This document is written as a companion to the *Framework for Information Literacy for Higher Education* (the Framework) for the ACRL Science and Technologies Section. While there is some duplication for clarity, it is generally avoided for brevity. The two documents are meant to complement each other, and knowledge of the *Framework* is assumed.
2. The primary audience for this document is higher-education librarians who work with Science and Technologies disciplines.
3. The format selected replicates that of the *Framework* for ease of reference. As with the *Framework*, this is not a prescriptive document. The frames are presented alphabetically. While the order of Knowledge Practices and Dispositions listed is not random, no relative importance should be placed on teaching or designing learning outcomes based on the order presented. Nor is it intended that these be taught in any

particular order. The intent is that librarians will work with concepts and skills based on the class, course, or institutional curricular need.

4. Each frame is designed to be read in its entirety. The narrative portion offers an overview, and the Knowledge Practices and Dispositions support and contextualize the narrative. As with the *Framework*, these are not exhaustive, and libraries may find it appropriate to develop specific outcomes to serve local needs.
5. This is meant to be a living document. The ideas and concepts within it should be continually evaluated and challenged. Through deeper understanding this document can be consistently improved, and IL librarianship in science and technology fields pushed forward.

Authority Is Constructed and Contextual

Authorities in science, engineering, and technology traditionally rely on evidence-based, reproducible research using the scientific method. However, it's important to recognize authority's constructed nature and be able to use critical thinking and information skills to dissect claims to authority to assess whether they are well founded, and that authority in one area does not necessarily convey authority on every subject or in every context.

Authority is traditionally conferred based on a scaffolded series of scholarship and training within higher education (e.g., BS - MS - PhD), wherein junior researchers learn from more experienced senior research faculty in order to formally join the scientific community. However, authority within science and technology can also be gained by experience and knowledge outside of traditional higher education, such as in employment in a related field; personal pursuit; and traditional, ancestral, or community knowledge, with such informal authorities contributing to the growing community science movement. Authority in science and technology is largely based on western-centric systems of scientific communication and privileges certain voices over others. Western academics operate within a system of tenure and reappointment that prioritize publication in high-impact and often English-language journals, which perpetuates those contexts of authority. Novice learners may depend on these markers of authority in their introduction to information in the field, while expert learners will consider the context, systems of power, and limitations to different definitions of authority in a broader way.

Knowledge Practices

Learners who are developing their information literate abilities:

- define different types of authority in the sciences, including scholarship, societal position, or special experience, including those not as often acknowledged outside of traditional Western systems (e.g., publication in journals);
- use indicators in determining authority, including recognizing the complexity of the value of listing author credentials (e.g., PhD) and affiliations in published information to help determine traditional academic signs of credibility;
- understand the role, as well as limitations, of high-impact journals within a scientific field or discipline;
- acknowledge that the scientific community exists in part to verify and check one another's work through standardized practices such as the peer-review process,

replication studies, comments on pre-prints, and editorial materials on published work;

- understand that authorities in science and technology share information in a variety of formal and informal formats and mediums;
- correctly cite others' work and build on research practices from experts in the field while also developing their own authority within the discipline;
- recognize that science is a community that functions to connect experts in a field with one another and share that information with the general public, knowing that the information gained from scientific research has wide impacts on daily life;
- know there is authority in effectively applying STEM knowledge to solve problems or design something that works; and
- understand that markers of authority change and shift over time, both personal (e.g., as a person develops expertise, authority might become more granular) & historical (e.g., engineering moving from an apprenticeship model to a degree-based model).

Dispositions

Learners who are developing their information literate abilities:

- understand that scientific consensus is based on the existing body of evidence, using review and evidence synthesis publications to gain an idea of that consensus, while also recognizing that some areas of research may not have reached consensus and that there is controversy within science;
- are motivated to find authoritative sources, whether subscription or open, recognizing that authority may be conferred or manifested in unexpected ways;
- dissect claims to authority to assess whether they are well-founded for the context in which they are made;
- critically approach published research for bias, flaws in methodology or data analysis, and identify funding sources and other potential conflicts of interest;
- value updates, corrections, and retractions as part of the iterative process of scientific knowledge creation;
- value the approaches that members of non-hegemonic scientific communities (community science, Indigenous knowledge, etc.) may apply to assess or evaluate authority; have the humility to seek out and learn these methods of

evaluation when appropriate; and

- understand that Western systems of authority are impacted by the structure of tenure and reappointment in academia (e.g., number of publications in high impact journals).

Information Creation as a Process

In the sciences, format denotes many things to an experienced user, including authority, stage of project, process, and credibility. While the dominant format in science remains the published peer-reviewed research article, scientists have taken advantage of the digital age to challenge traditional publishing practices, resulting in new processes and formats.

In STEM disciplines, the research/design lifecycle may result in different information products (e.g., data sets, code, models, plans, mathematical proofs, presentations, prototypes, articles, patents, reports, practitioner guidelines, reviews/meta-analyses) at different parts of a single research project or in science industry and design work (e.g., engineering). Expert learners recognize how each kind of information is created, reviewed, and disseminated, the stage in a project in which the information was created, and the audience it is created for. Expert learners seek out information products that fit their information needs and may look for multiple formats related to one project.

There are different kinds of organizations that create and disseminate STEM information, both in professional spaces (e.g., academic, government, professional organizations, scholarly societies, medical, industry, community science) and more broadly in society (e.g., traditional and social media). These organizations may rely on different kinds of information creation processes resulting in varying products that were created for different information needs. While novice learners may rely on more traditional formats and processes, advanced learners start to develop a deeper understanding of creation processes relevant to their work and discipline and participate in creating information in those formats. Expert learners place varying value on information depending on its creation process, and Western STEM disciplines have traditionally prioritized peer review over other modes of communication; non-Western cultural models may place more value with other information products or products at other stages of creation. Expert learners may start to challenge traditional information creation processes in order to increase speed of transmission, equitable access, and other problematic aspects of traditional modes of STEM communication, for example, the use of pre-prints, or dissemination through social media. Part of the creation process is picking a mode of dissemination, which experts realize affects the access and impact of their work.

Finally, the dominant information creation process for STEM disciplines is based in western-centric traditions of sharing information and often favors majority groups and disadvantages those not in the dominant group. Expert learners recognize the ways in which non-majority voices may be marginalized and disadvantaged by the traditional process of creating and sharing information and take actions to address these inequalities.

Knowledge Practices

Learners who are developing their information literate abilities:

- describe the traditional and emerging processes of information creation and dissemination in STEM disciplines;
- articulate the capabilities and constraints of information developed through various creation processes, especially with regard to creation processes specific to STEM information;
- reflect on disciplinary or cultural traditions or biases that affect how different kinds of information are perceived; and
- develop, in their own creation processes, an understanding that their choices impact the purposes for which the information product will be used, the message it conveys, and the audience that may have access to it.

Dispositions

Learners who are developing their information literate abilities:

- understand that peer-reviewed articles are often, in Western tradition, considered the most credible form of communication in STEM, but other more open and immediate formats such as preprints or social media are valuable in their speed and breadth of dissemination;
- are aware that scientists must communicate information to a wide variety of audiences via different formats and voices or communication styles and select the format that best fits the audience they want to reach;
- are inclined to evaluate the advantages and disadvantages of various information creation processes and formats, in multiple cultural traditions.

Information Has Value

The production, dissemination, and application of scientific information is a complex ecosystem, in which power, monetary resources, and social capital influence how that information is accessed, used, and shared.

Science communities are both active and passive participants in the information economy. Scientists use information as a tool to solve scientific, medical, and technological problems. Novice learners will participate in this process through valuing the property and information generated by others. Novice learners will also be aware of constraints imposed by cost or availability of information; as they develop in their information and disciplinary practices, they will gain understanding of the forces behind barriers to access. As active participants in the information economy, expert users act as agents for the value of their own information, possessing and practicing knowledge of intellectual property, copyright, and the complicated aspects of the commodification of information they generate. Scientists are also affected by the larger structures of commodified information, as these systems impact research agendas, funding availability, and the larger scientific discourse.

Knowledge Practices

Learners who are developing their information literate abilities:

- give credit to the original ideas of others through proper attribution and citation, including non-traditional formats such as social media, code, data sets, government information, and etc.;
- understand that intellectual property is a legal and social construct that varies by culture and scientific discipline;
- articulate the purpose and distinguishing characteristics of copyright, fair use, open access, and the public domain within the sciences;
- understand how and why some individuals or groups of individuals may be underrepresented or systematically marginalized within the structures that produce and disseminate information, recognizing that scientific literature is usually the result of funded experimentation and that some populations, regions of the world, and disciplines are more able to fund research than others;
- understand that without regular access to published scientific literature it can be

difficult to conduct research and publish in turn;

- decide where and how their information is published, realizing that some journals in the sciences are considered core, that metrics and alt-metrics can reflect this, and that publishing decisions for scholars in higher education are often made in view of tenure and promotion requirements;
- understand how the commodification of their personal information and online interactions affects the information they receive and the information they produce or disseminate online, including issues related to privacy;
- operate with an awareness of the impact the scientific information they generate has on the larger information systems of the discipline and the communities beyond;
- consider how Open Access impacts the perceived “value” (cost, time, effort) of different stages of the publishing cycle;
- understand that the value of information is based on cultural norms and world views as well as the commodification of intellectual effort and time investment of an individual, community, or organization such as traditional knowledge, industry standards, patents, and disciplinary frameworks;
- Understand that information products, such as articles, databases, and patents, have a cost, but that cost does not directly reflect the value of the information (the labor of creation, the labor of production, or vendor inflation); and
- Recognize that an information ecosystem exists, which can be used to support or exploit library, academic, and research work in furthering science.

Dispositions

Learners who are developing their information literate abilities:

- respect the original ideas of others;
- balance the value of open science with respect for privacy, cultural valuation of knowledge, and protection of vulnerable populations and places;
- value transparency in research to advance the scientific agenda;
- are inclined to examine their own information privilege and incorporate actions to address it;
- value each role in the research and publication process, with an awareness of how power asserts itself in research and resulting publication credit;
- use discipline and culturally specific forms of information such as patents, standards, protocols, and procedures appropriate to the value and role the information plays in the

scholarship of the field.

Research as Inquiry

The iterative nature of research mirrors that of the scientific process, in which new inquiries are scaffolded upon existing research, and the questions raised through this work leads to even more questions to explore.

In STEM fields, the iterative nature of research is fundamental and well understood by experts but is equally sometimes concealed by popular notions of scientific certainty and traditional pedagogies of science that have focused on memorization and facts. Reframing scientific research as inquiry can pose a challenge to novice learners who have primarily written reports or performed labs that "work" or "don't work," but the notion that scientific research is a process of continual exploration and refinement is foundational to expert participation in science.

Expert learners see inquiry as a process that focuses on problems or questions in a discipline or between disciplines that are open or unresolved. Expert learners recognize the collaborative effort within a discipline to extend the knowledge in that field, which is particularly intense in the sciences where researchers ranging from just two to thousands may serve as topical experts in a collaborative project. This effort is also present in the design and prototyping process in technical disciplines such as engineering and computer science. Many times, this process includes points of disagreement where debate and dialogue work to deepen the conversations around knowledge, although this disagreement or debate may be somewhat cloaked in the scientific language. This process of inquiry extends beyond the academic world to the community at large, and the process of inquiry may focus upon personal (for example, seeking health information), professional (for example, seeking appropriate mathematical or statistical analyses to ground a decision), or societal (for example, understanding rates of neighborhood exposure to chemical pollutants) needs. This exploration, then, can happen in multiple scientific and technological arenas including academia, industry and professional organizations, community science and broader society. The spectrum of inquiry ranges from asking simple questions that depend upon basic recapitulation of knowledge (what species belong in a local pollinator garden?) to increasingly sophisticated abilities to refine research questions (how to use fluid dynamics to understand blood flow in designing an artificial organ), use more advanced research methods, and explore more diverse disciplinary perspectives. Science education often relies on recapitulation of knowledge in early collegiate years and articulating this as an initial form of inquiry is important to help novice learners bridge into expertise. Novice learners acquire strategic perspectives on inquiry and a greater repertoire of investigative methods. As they progress toward expertise, learners value asking research questions without assumptions; that rather than trying to find some sources that “prove me right”, they use the literature to discover new paths of inquiry and explore their research question, building on the research that has come before.

The inquiry process both in information literacy and in science and technology research and design is based on a Western tradition of asking questions. Expert learners understand that there are other traditions in which inquiry is approached differently in other ways of knowing and learning, and that there are benefits to different approaches.

Knowledge Practices

Learners who are developing their information literate abilities:

- recognize that the scientific consensus is based on existing evidence which may change over time;
- monitor gathered information and assess for gaps or weaknesses that are opportunities for further investigation;
- synthesize ideas gathered from multiple sources; whether that be by synthesizing published research in new ways (literature reviews, meta-analysis), reusing data to build new models or answer new questions, or conducting empirical or observational research (primary research articles);
- seek multiple perspectives during information gathering and assessment, including those from non-dominant or non-Western traditions, including ethical, global, economic, environmental, and social perspectives;
- reconcile information drawn at various stages of the information creation process such as raw data, pre-prints, and published research;
- draw reasonable conclusions based on the analysis and interpretation of information;
- pose questions and seek appropriate help when needed; and
- acknowledge non-Western and/or indigenous approaches to scientific inquiry and knowledge gathering during the research process.

Dispositions

Learners who are developing their information literate abilities:

- consider research as open-ended exploration and engagement with information, understanding that the occasional emphasis on recapitulation of knowledge is a base from which to build more complex inquiries;
- appreciate that both foundational and novel questions may bel disruptive and both are important to research;
- value intellectual curiosity in developing questions and learning new investigative methods;
- maintain an open mind and a critical stance, understanding that the objective tone of scientific writing can conceal critical debate and discussion;
- demonstrate intellectual humility (i.e., recognize their own intellectual or experiential limitations);
- approach scientific inquiry with persistence, adaptability, and flexibility, recognizing that ambiguity and iterative approaches can benefit the research process;
- adapt continuously to new information throughout the research process;
- recognize an ethical responsibility as a practitioner to consider implications of research questions and answers on society as a whole; and
- in doing the above, exhibit and exemplify the principles of scientific research and technical design and prototyping mirrored in their information research.

Scholarship as Conversation

Science communities engage in conversation giving rise to new discoveries across scholarly, research, and industry applications, using both prior and emerging discourses from a diversity of disciplines and approaches.

The scholarly conversation in the sciences is both established and in flux. A well-established system of peer-reviewed journal and conference publications coexists alongside emerging practices, such as data and code publication, and new forms of communication, such as open peer review, preprint servers, and post-publication peer review. Novice learners begin their participation in these practices in mostly passive ways but develop more active and authoritative voices as they become more comfortable with the scholarly conventions of the field. Expert STEM researchers have learned to understand the established system and appropriately deploy new practices as well. This scientific discourse also takes place beyond academic and research institutions, flourishing in communities of practice like industry, government, or other organizations. Recognition, participation, and valuing of these conversations is essential to the scholarly scientific discourse.

Knowledge Practices

Learners who are developing their information literate abilities:

- effectively read and get needed information from established written scientific formats and learn to judge the quality of that information in the context of other voices in the scholarly conversation;
- follow the scholarly conversation through time by properly citing the contribution of others in their own work and new scholarly products;
- contribute to scholarly and/or professional conversation at an appropriate level and in venues valued by their discipline and community of practice, such as local online group, guided discussion, undergraduate research journal, conference presentation/poster session;
- identify the contribution that particular articles, books, and other scholarly pieces make to disciplinary knowledge, whether those are foundational paradigm shifts or incremental advances;
- summarize the changes in scholarly perspective over time on a particular topic within a specific discipline;

- recognize that a given scholarly work may not represent the only or even the majority perspective on the issue; and
- establish an appropriate level of authorial presence to demonstrate active participation in the scholarly conversation of their discipline.

Dispositions

Learners who are developing their information literate abilities:

- recognize that the conversation includes debate and controversy;
- seek out conversations taking place in their research and/or professional area, as well as relevant research beyond their specific discipline;
- understand the responsibility that comes with entering the conversation through participatory channels, which includes valuing disciplinary ethical standards for creating and disseminating information, academic integrity, and conflicts of interest;
- critically consider disciplinary and systemic barriers to participation in scholarly conversation; and
- acknowledge barriers in access to the products of scholarly conversation affects the conversational possibilities for and by governments, organizations, businesses, and the general public.

Searching as Strategic Exploration

The nonlinear and iterative aspect of searching for information is an essential aspect of many models of inquiry in STEM and requires not only selecting the best sources from a range of options, but also an understanding of the information structures within STEM fields across knowledge systems.

Exploratory and iterative search is part of the scientific method, the engineering design process, and the Traditional Ecological Knowledge (TEK) model. Complex research questions or design problems can be broken down into core concepts and the relationships between them identified. It is important to learn specific jargons and taxonomies of multiple disciplines and epistemologies (including TEK) to be able to effectively search for information.

As science, technology, engineering, and math become more interdisciplinary and multidisciplinary, developing a contextualized, complex skill set for searching is increasingly important. Experts understand the importance of being strategic and expansive in searching for relevant information sources. Novice learners may search a limited, familiar set of resources, while experts may search more broadly and deeply to determine the most appropriate information within the project scope. Likewise, novice learners tend to use few search strategies, while experts select from various search strategies, depending on the sources, scope, and context of the information need. This includes being able to transition between discipline-specific jargon, incorporate culturally specific concepts, multilingual search terms, and embracing curiosity when searching.

Knowledge Practices

Learners who are developing their information literate abilities:

- identify interested parties, such as scholars, organizations, governments, industries, community experts, and those with experiential knowledge who might create or hold information about a topic; and then determine how to access that information;
- understand how information systems (i.e., collections of recorded information and oral traditions) are organized in order to access relevant information; learners use critical thinking skills to navigate curated data information systems; and
- use different types of searching language such as controlled vocabulary, keywords, natural language, and specified language for the field (including

chemical compounds and patents);

- recognize that scientific literature is filled with jargon that must be understood in order to search effectively, and that a strong search may require professional or scholarly jargon as well as common names;
- manage searching processes and results effectively, understanding how to interpret data, diagrams, and other schematics in ways that stay true to the information; and
- design and refine needs and search strategies as necessary, based on search results.

Dispositions

Learners who are developing their information literate abilities:

- integrates transferable strategies and knowledge into future searches;
- understand that first attempts at searching do not always produce adequate results, and that searching is a process just as any other form of research, and may take multiple attempts and also a variety of search terms and criteria in both scientific and common as well as structured and natural language;
- assess the scope of their information need and seek sources in accordance with that need (e.g., a search for proof of concept, versus a search across the literature to author a systematic review);
- realize that information sources vary greatly in content and format and have varying relevance and value, depending on the needs and nature of the search; and
- seek guidance from experts, such as librarians, community experts, researchers, and professionals.

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Appendix I

Process for the Creation and Revision of the STS IL Framework for Information Literacy in Higher Education

Following the Association of College and Research Libraries' Information Literacy Frameworks and Standards Committee (ILFSC) "Checklist for Developing and Reviewing Framework Companion Documents," the STS IL Framework Task Force (STS FTF) was appointed in March 2018. The STS FTF began their work by reviewing the environment around the existing and former documents guiding information literacy (IL) development in the STEM disciplines. Research and documents in the existing STEM IL Lit Review, as well as sub-discipline standards and guidelines, and new research related to STEM and IL development in higher education were all considered. This also included the disciplinary work around threshold concepts indexed by Meyer and Land on their Threshold Concepts website (https://www.ee.ucl.ac.uk/~mflanaga/thresholds.html#spectop).

Simultaneous to this work, the STS FTF also administered a survey to a variety of stakeholders, including the STS membership, the STS Liaison committee, affiliated library and information organizations supporting the STEM disciplines, and STEM professional, research, and higher education organizations. This survey addressed the perception and use of the general Framework in the STEM disciplines, IL skill development and needs, and IL teaching and learning environments, including campus collaborations and task forces.

Once this information was gathered and collated, the STS FTW drafted the document objectives and goals. The STS FTW then drafted a single frame, "Scholarship as Conversation," to set the tone and format of the document. Following the drafting and review of this frame, the STS FTF worked in pairs to draft each of the five remaining frames; the frames were reviewed as a whole, and then the pairs "rotated" to a new frame to incorporate feedback and discussion notes. Once the entire Framework was drafted, a subteam of editors reviewed and standardized each of the frames. The final first was completed and shared with the larger STS membership and stakeholder groups.

Concurrent with publicly releasing the first draft, the Task Force announced a series of seven online, open-discussion fora, as well as encouraging participation in online surveys to provide feedback. The forum sessions were recorded and transcribed for later review, and notes were taken during each of these meetings. Different members of the task force were present at each session, with the two co-chairs attending all of them.

The surveys, made available at the draft release, remained open for one week following the conclusion of the final forum. At that time, the task force began critically reviewing the feedback by looking for common themes and major points raised in the surveys and in our discussion notes. To facilitate this, Voyant was employed to analyze much of the qualitative data. the STS FTF was split into teams to focus and work on individual frames (two per team), armed with the results of the qualitative analysis of the feedback.

A kanban-style master list of changes to be reviewed and either incorporated or rejected was kept, and as teams dealt with critical feedback, items were checked off the list. When this work was completed, the co-chairs made several global changes for consistency and style. Finally, the task force returned to review the document as a whole.

The document was then submitted to the STS Executive Council for review and approval. The STS Council reviewed and voted to approve the document on July 16, 2021.

Appendix II

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