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Finding the Win:

Transforming STEM Learning and Information-Seeking Experiences

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In this chapter, we use the theory of transformational learning to explore how we have worked to change their self-conceptions around expertise, information need and use, and the role of the STEM librarian. By reframing our beliefs around how to present instruction on information literacy to STEM students, we were ultimately able to change faculty perceptions of library partnerships, and student behaviors around information seeking and use. Our work was underpinned by re-conceptualizing how librarians operate as educators within the STEM context, moving instruction to lab courses, critique settings, and communications requirements to present the idea of information evaluation as foundational to STEM. By envisioning the ability to be critical of information as the core threshold concept of STEM information literacy, we give voice and space to different ideas and perspectives while fostering critical reflection in the classroom space. This pedagogical approach trains STEM students to develop the habits of mind that allow them to engage in the construction of knowledge, self, and society that will enable them to move forward as fully realized professionals.

In this chapter, we present a case study on how two librarians—one with a STEM background and one with a background in education—worked to change our practice and to communicate and re-frame information literacy in ways that build connections and resonate with STEM faculties and adult learners. Specifically, we address

- aligning information-seeking with the scientific process for students across STEM fields;
- changing student behaviors toward information use by re-framing reference interviews to known critique processes used in engineering design courses; and
- work to support users in navigating information overload.

Making these changes has shifted our educational practice toward an emphasis on critical evaluation of information and fresh approaches to other supports, including participation in critiques and supervision of students and capstone groups. This change to practice transforms the role and approach of the librarian to one where we can effectively assist STEM students in making active and critical choices about their information behaviors while using the act of critique to help students revise belief systems and understand information as intimately woven into the act of doing and being scientists.

DISORIENTING DILEMMAS AND CATALYSTS FOR TRANSFORMATION

Librarians can have a difficult path to effectively connecting with faculty and students in science, technology, engineering, and math (STEM) faculties. Foundationally, the concept of information literacy and the stereotypical perceptions of what a librarian does is misaligned with the STEM context.[1] STEM areas of study focus on asking questions and getting answers by finding evidence, conducting experiments and original research, and training in processes, and all too often the perception is that libraries are a study space and librarians point you to where you can find a book. This misalignment comes from a lack of shared context, language, and worldview, emerging from communication issues around expertise, resources, ability, and ultimately a lack of creativity embedded around partnership building. Ultimately, information literacy as a concept has apparent alignment in social science and humanities contexts, but in STEM it is often brushed aside due to these communication failures. This breakdown leads to a series of questions about how we communicate what we do when we tend to speak a different language.

In parallel, information has never been more crucial or more intimately engaged in the work of STEM as it is at present.[2] Information is being created and disseminated in ways that are enhancing connecting, driving innovation, and speeding up the process of discovery in amounts that have never been seen before.[3] The COVID-19 vaccine success is the easiest example, but similar ones abound—electric cars, artificial intelligence advancements, CRISPR-Cas9, and others have upended how we understand our planet, human history, the search for alien life, and how we innovate new health discoveries. The interplay of information and scientific discovery is intimately intertwined with the theory of transformative learning, which posits that learners introduced to problematic or complex ideas are forced to constantly reassess and adjust their personal value systems and beliefs.[4]

EXAMINING, EXPLORING, AND REFLECTING

Science education is built on the idea that understanding the structure and nature of science ultimately makes students better at doing science—by building awareness of patterns of observation, evidence, and building hypotheses, students will be best able to build their knowledge.[5] Student conception of the nature of scientific knowledge has long been one of the most significant goals of science education, and science students are asked to adopt a worldview that requires continuous assessment of values, assumptions, beliefs, and existing knowledge in alignment with transformative learning.[6]

When librarians approach introductory information literacy instruction only as an opportunity to train students in the use of library-approved resources, there is a missed opportunity to work within the framework of building scientific knowledge. Science is fundamentally a body of knowledge that includes concepts, ideas, theories, and laws that are represented through scientific texts, which at the level of generalizability implicit in early scientific instruction (i.e., K-12) and up through early baccalaureate education there is very little disagreement of what is foundational scientific knowledge. These include that scientific knowledge is tentative, empirical, subjective, involves human inference, and is culturally embedded.[7] At the point where early librarian intervention around resources is often brought into STEM courses, it needs to work with these ideas, mimicking the established language used by science faculty and echoing the concepts in a way students are already learning.[8] Moving information literacy approaches to reflect the theory and pedagogy of transformative learning can begin to bridge the silos, pushing students, faculty, and STEM librarians into an interactive dialogue around the purpose, application, value, and credibility of information across varied contexts. This aids in the development of student agency and autonomy in their approach to and use of information while exposing ingrained biases and systemically overlooked information sources.[9]

Effective and accurate information-seeking underpins STEM students' ability to succeed both during their academic careers and as they become professionals in their chosen fields.[10] Within higher education, students most often depend on Google as a first-line resource.[11] In a STEM context, the information available through Google for people learning can be as valid and good as that which they would find in an introductory textbook.[12] Similarly, we are seeing an increasing movement toward students using Reddit or Discord Threads, Tweets, and other forms of social media to either find or validate their learning and use of formulas or methods.[13] In many cases, Google Scholar and Wikipedia are seen as the next level of rigor toward validating information without the necessary context, and while much of the information available through Google Scholar may be valid, it cannot be *guaranteed* to be accurate.[14] However, these more casual information sources are widely used by STEM students as they are presented in a more user-friendly and digestible manner than traditional academic sources.

For librarians to engage effectively in STEM contexts, they must acknowledge their learners as individuals with extensive experience finding and using information as a whole in alignment with expectations for adult learners.[15] When students begin with STEM in higher education, they begin with ubiquitous foundational knowledge—first-year biology, chemistry, and physics labs are generally the same no matter at which institution one does a program of study.[16] The information itself is the same. Between peer and institutional knowledge-sharing supplemented by the foundational information available on sites such as Wikipedia, the information necessary to be successful at these labs and courses is easily available. The first, second, and often third years of study are guided largely by specific requirements that were developed to build foundational knowledge to an extent where one has the knowledge and context to potentially begin one's own process of scientific discovery.[17] This idea of building knowledge is meant to underscore the assumption that it is both the generation of ideas and the justification of those discoveries that drives science forward.

BUILDING SKILLS AND CONSTRUCTING KNOWLEDGE

In STEM fields, traditional training around information-seeking has focused on building knowledge: learners begin with learning foundational knowledge, most commonly found in lectures and lab experiences, reinforced through textbooks, then, as a student progresses through their education, they move to use peer-reviewed journal articles and other scholarly sources.[18] In parallel, students arrive at university with direct, lived experiences that have trained them to interact with information in a casual "I will just Google it" manner throughout their lives. This combination of focus on both repetitive fundamentals and casual information-seeking in the first two years of STEM curricula reinforces information behaviors that ask for little critical thought around the content, quality, or use of information in STEM disciplines.

Further complicating the information landscape, students face is an overwhelming ecosystem where information and misinformation are presented as one and the same.[19] The complexity of information and misinformation has wide-reaching ramifications, especially in relation to expertise, which is being questioned at levels to which it never was before, with politics increasingly shaping the conversation around science.[20] Understanding authorities and experts necessitates a deeper understanding of not only the information itself but also of how and why information is being shared and used by students.[21]

It is easy to teach a student to trust a textbook, but when other experts, both real and perceived, are giving information in an easily accessible public-facing way, the conversation quickly becomes complex. We must begin to shift our mindset to meet our learners where they are and teach them approaches to navigate across the spheres. One aspect of encouraging students to think critically is to acknowledge that Googling itself is fine, but they need to do so using academic tools such as RADAR or CRAAP to help accurately contextualize their findings.[22] It can seem simplistic to not only allow but also encourage students to Google, but the end result is they learn that the time it takes to accurately critique an information source they find online can ultimately take longer than beginning with academic sources.

To address students' learning and information-seeking needs, librarians need to develop techniques and tools that encourage students to reflect on why they are using a piece of information, the inherent limitations or biases of any information, and how their own perspectives and habits naturally impact the information they find and choose to use. Specifically, it is helpful to begin a process of self-reflection and self-critique on why we as librarians place an explicit or implicit preference for one type of source over another.[23] Librarians introducing and centering their teaching practice on such reflection have the potential to positively engender transformational learning as faculty in STEM fields tend to engage less frequently in explicit reflexive teaching practices or model such practices for their students.[24] On the whole, academia places a higher value on peer-reviewed sources that are often found behind a paywall. By promoting these sources over other sources such as Indigenous knowledge and ways of knowing, Reddit-based threads, Stack Overflow, blogs with lived experiences of marginalized groups, we ultimately perpetuate entrenched academic cultural norms that misalign with both modern information needs, including STEM discipline-specific knowledge. As Liu states, "We cannot conduct a real

information evaluation until we look deeply into the source content and assess the arguments."[25] Building on traditional approaches to information evaluation, it is also crucial to teach students to identify and evaluate the social, cultural, and technical *contexts* in which the information was created and intended for use and in which students themselves are functioning and contributing.

PLANNING AND PILOTING IN PRACTICE

Teaching students to align their information behaviors with the needs of the academic environment while learning to respect alternative perspectives and sources is no small feat. To do so is further complicated by the need for librarians to establish practices that allow for this effort within the context of the one-shot instruction session as it is most reflective of the time available for such work.

To do this, we use a four-step process within the bounds of a single guest lecture, typically lasting an hour to an hour and a half. These steps include finding a source through any means comfortable to the student (e.g., Google, Wikipedia, Reddit), asking students to apply an existing evaluative framework of their choice to the source (e.g., RADAR, CRAAP, SIFT) and an interactive discussion where students mirror the established STEM process of critique to discuss and contextualize the source, drawing from the discoveries of applying the evaluative framework and their own lived experiences as *applied to a specific problem or question*.

- Step one: define context
- Step two: find a source
- Step three: use an evaluative framework
- Step four: critique

The process itself is simple. Students listen to a brief interactive lecture about information-seeking and how it is used in scientific inquiry and then are told to go find a source of information that they feel is relevant to the topic they are examining. This process is inherently scalable from a first-year general introduction course to a final-year capstone or thesis project. After students have found a source, they are provided with an evaluative framework of the librarian's choice (e.g., RADAR, CRAAP) and asked to systematically address each of the elements of the acronym as it relates to their found source. Finally, students are asked to participate in a critique-focused classroom discussion on their sources. They are asked to explain if they think a source is good or bad, if they would use it, why they would use it, and why they chose it above other sources. It is essential to tie the discussion to a project the students are doing in the class or their program. By relating it to something they are doing, students have a context in which to place the information source. If there is no project for the student to relate to this process, a sample problem or question can be provided to them to establish a context in which to find a source of information.

Critique is used by several fields as a tool to coach and support students as they work through a design process to learn by doing.[26] In ideal cases, by acting as a mentor rather than an evaluator, such as is more traditional in lecturing or tutorials, the critique process can provide students with ideas and suggestions in a structured way that can improve the

learning process.[27] By working under a critique lens, the interaction around discussion can benefit both the person or group being critiqued as well as those observing the critique. A critique is essentially a process that is intended to challenge assumptions, abilities, ideas, and processes—in this case, specifically centered around one source of information. To effectively critique information, students must gather adjacent information, synthesize it, and then clearly communicate it to their colleagues and instructors in the class.[28]

The idea, fundamentally, is that librarians must have enough knowledge to clearly explain and justify why a chosen source is the "right" source to use and to be open to receiving feedback about the information and the sources. This process works equally well to justify using a source of information and to justify *not* using a source of information, and it is applicable across many areas of study, not simply engineering and studio-based settings, making it ideal for multidisciplinary learning.[29] Giving students the courage and tools to clearly explain why they feel a source of information is not relevant or useful intentionally combats an increasing culture of using the first sources that are found or that are "close enough" to what is needed. Additionally, the process of having a source openly discussed, potentially debated around strengths and weaknesses, and that is accurate, safe, and effectively contextualized develops skills and fosters a culture of students who are confident in discussing successes and failures equally around information-seeking.

TAKING TRANSFORMATION FORWARD

Implications for Practice

As practitioners in the classroom, we have had to learn to let go of many of our own ingrained concepts and habits of what is "best" for students or what they "need" to know. Doing so has resulted in letting go of the terminology "information literacy" itself and instead focusing on building from existing student experience in searching for and finding information. In other words, we do not talk about information literacy, we talk about how information is used and is needed within the STEM fields, and we let students use Google with abandon. These practices have been well received, with faculty members encouraging this move and focus. As a result, we have had very high uptake of this type of one-shot guest lecture. Further, when introduced in the first year, our work has led to continued invitations and integration opportunities later in the curriculum. While these results are colloquial in nature, the increases in instruction indicate such an approach is impactful, if cognitively dissonant for individual librarians.

This approach to teaching information literacy builds from the theory of transformational learning by simultaneously meeting learners where they are and building from foundational knowledge, meaning, and experiences, while providing a pathway to consistent, sustained changes in perspective through the reflective intake of new information.[30]

How Transformative Learning Theory Has Changed our Thinking

We would like to emphasize the value of aligning LIS instructional pedagogy with processes and techniques familiar to STEM faculty and students, such as the critique

process. By doing so, librarians can help STEM students develop skills to be successful in their academic and professional careers by modeling familiar action types—telling, listening, demonstrating, and imitating. This process exists within STEM education but is foundational to the theory of transformative learning, where individuals take in new information and evaluate past knowledge and understandings in light of this newly acquired knowledge.[31] Feedback, through the critique process, allows for in-depth communicative learning, where people share their perspectives, values, interpretations, and instrumental learning as they apply this knowledge to task-oriented problem-solving. Further, the application of the learning to real-world problems, integration of lived experience as knowledge, and the potential for the critique to result in "assumptions [that] are found to be disorienting, inauthentic, or otherwise unjustified."[32] For these elements to occur in the classroom, a trigger event must stimulate transformative learning and precipitate changes in student understanding.[33] Within STEM fields, the introduction and use of information evaluation into the critique process, as outlined in the theory of critical evaluation of information (CEI), holds significant promise to act as just such a trigger event for transformative learning.

By integrating CEI into the practice of critique, librarians can experience transformative learning alongside students. There is a known connection between self-reflection and effective pedagogical practice,[34] and while the idea of transformational learning is well reflected in the LIS literature, it has not been thoroughly examined in STEM information literacy contexts.[35] Given the state of the current information landscape, librarians can no longer teach using only traditional information literacy approaches. Using and developing new models that can adapt and address diversity and the breadth of information used by students in their academic, professional, and personal lives. Arguably, the most significant takeaway and professional growth for us is that this learning needs to not only reflect the student perspective but also, fundamentally, the librarian perspective. It can result in transformational learning for librarians as we relearn our approach to how we understand, contextualize, and promote information literacy to our students. By partnering with STEM scholars and students, librarians can engage and teach information practices that actively encourage the continual re-conceptualization of belief systems that respect the lived experiences *everyone* brings to the classroom.

Building a Scholarly Foundation

There is not a substantial body of research on this area of study. We are currently focused on building a body of evidence largely focused on engineering students.[36] At the same time, other researchers are gathering data about and making sense of similar research inquiries.[37] In our preliminary results, we see a positive change with measured student learning outcomes, and there is a significant opportunity to partner across institutions and fields of study to conduct a more holistic investigation across STEM disciplines and contexts.[38] We are currently partnering with various colleagues to study the impact doing so has on student learning and our professional pedagogy. Initial results have indicated good stuff, but we would still like to see a more holistic investigation across all STEM disciplines as our research to date has focused on engineering students.

Beyond our efforts to study this approach, we have been invited to engage in discussions, workshops, and seminars on this topic. The discussions are aimed at fostering dialogue both within and external to the LIS profession to help formalize the pedagogy and root the practice in evidence. We have also recently been awarded a provincially funded grant to create asynchronous materials covering these concepts that will be published as open educational resources. We hope these efforts will add to the scholarly discourse around STEM library information literacy instruction and catalyze new pedagogical practices for STEM librarians that integrate with the established methods of those disciplines.

Future Directions

Librarians are keenly aware that the world around information has changed. We know information needs to be more accessible, inclusive, and acknowledge the information burnout landscape. In parallel, in STEM, most practices have been deeply rooted in gendered and colonial paradigms, and we are obligated to question our own privilege, colonial mindsets, and existing gatekeeping practices. While foundational texts and academic information still have an important place, conceptualizing information more broadly can enhance conversations and build skills that both respect and question traditions. This future work will be essential to establishing information paradigms that align librarians and the practices of STEM professionals and are inclusive, equitable, and diverse.

While no journey of transformation is ever truly complete, we cannot accomplish our goals in this endeavor until we are willing to examine our ingrained habits and practices as librarians. Our own LIS education and its emphasis on directing students to the library for quality information can prevent us from effective work within STEM fields; we must value the application of all pertinent information, independent of where that information was sourced. It is only if we can align ourselves with the needs of our learners, our faculty partners, and STEM professionals that we will truly transform our practices and ultimately find the win.

CRITICAL REFLECTIONS FOR INSTRUCTIONAL IDENTITIES

As you consider your own opportunities to find the win, we hope that these questions will help you to consider your work or institution in a new light.

- Why do we place more value on peer-reviewed papers?
  - We need to consider and acknowledge that a peer-review focus leaves out the lived experiences of historically marginalized people as a source of authority. Moreover, the priority on peer review fails to contextualize other ways of knowing, such as Indigenous knowledge. By being self-critical of the information sources we use in our teaching and acknowledging our often unspoken or unconscious practices, we can more effectively engage students and foster more meaningful learning.
- What is the value of letting students use Google and Wikipedia?
  - This approach meets students where they are, and it places the focus on finding

relevant information instead of specific types of information, consistent with STEM professional practice. Moreover, it also tops teaching information as a good versus bad paradigm and encourages consideration of contextual factors. Here, too, these experiences can help students begin to transform their thinking about research and information.

- How do our biases and lived experience contribute to our professional practice?
  - We need to actively question and check our bias prior to teaching, and we should think about how and when we can use our experience and skills to emphasize diverse voices, other ways of knowing, and different types of knowledge to improve inclusion. What's more, we need to make explicit the seemingly invisible biases and assumptions within higher education or the "academy."
- How can we train students to engage in the construction of knowledge, self, and society?
  - We can consider professional and societal values as one way to engage students. If information-seeking is made real, it can allow students to conceptualize their beliefs within their area of study and align their information behaviors with those beliefs.
- In our work as librarians, how can we change our practice to be more reflective of existing contexts, learning, and best practices of STEM education?
  - We need to identify both what we need to learn and what we need to let go of in our instructional approaches and perspectives on teaching. While design critiques in engineering are one way of doing so, there are certainly other ways to engage with students by using patterns and contexts already familiar to them. And we need to consider how the scientific process aligns with information-seeking, use, and dissemination to connect library instruction more fully to students' learning experiences.

NOTES

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