Resources and Exercises for STEM Educators and Students Navigating the "Misinformation Age"

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Teaching students how to research a topic and navigate source usage is an important part of preparing future professionals in any discipline. In STEM/STEAM fields, both professionals and students must keep up with the fast pace of innovation, making information literacy essential to professional growth. Source evaluation instruction in students' disciplines can help students identify the information sources most applicable to their research. Moreover, reading credible, current publications helps students learn the discourse of their discipline [1]. However, the complex range of sources and ways of searching available to students today require more nuanced source evaluation techniques and pedagogical approaches than in the past.

It is also important to acknowledge the connection between critical-thinking skills and source evaluation processes. For STEM students in particular, a fundamental learning outcome is developing and applying analytical skills. Source evaluation instruction provides STEM educators with an opportunity to reinforce those skills—an instructional topic that, critically, must no longer be relegated only to the purview of composition teachers and librarians—while helping students develop practical life skills that will make them more astute consumers of information in a continuously evolving digital environment.

Helping students recognize the characteristics and uses of scholarly, peer-reviewed articles is necessary and important in any STEM curriculum—a strong first step in teaching source evaluation. However, this is where many educators start and end the lesson. Limiting students to using peer-reviewed works from academic databases is no longer sufficient. In the Digital Age, it is increasingly important that students also learn how to navigate the web in their research. STEM students are required to pull information from a wide variety of sources [1], and, as such, should be equipped with the latest source evaluation techniques to combat the misinformation and bias they will undoubtedly encounter online. Students can only benefit from being able to recognize poor-quality content in real life and in real time.

This paper provides the new STEM educator with relevant background about how undergraduate students approach source evaluation, both traditionally and today. This work summarizes existing research to help new STEM educators understand and situate themselves among best practices in teaching source evaluation and information literacy to undergraduate students. Most importantly, it provides classroom-ready collaborative activities (some writing-based, all discussion-based) for a STEM educator to help students learn and implement source evaluation techniques in a manner that is engaging and efficient.

As students progress through the activities, they—and the new STEM educator—learn not only how to recognize a credible source in general (e.g., vertical versus lateral reading), but also to evaluate and incorporate sources written by non-subject-matter experts (e.g., how one may utilize research journalism and news reporting versus scientific and technical publications). Natural language processing (NLP) models such as ChatGPT are also included in the source evaluation exercises, reflecting emerging concerns about how they will affect research and writing.

This paper argues that source evaluation is a skill that must be taught in all STEM classrooms; the stakes for society of producing STEM graduates with a poor research foundation are simply too high. Just as STEM students learn to flex their critical-thinking skills to make reason-based professional judgments, they can apply those same critical thought processes to their personal media diets.

Historical challenges college students face in finding quality sources

The current understanding of how students approach research and source evaluation can be traced to Kuhlthau's foundational studies of the information-seeking process [2]. In the early 1990s, the growth of the internet led to dramatic changes in research methods; with the ability to access a wide range of sources quickly, students were faced with significant opportunities but equally daunting challenges.

Kuhlthau argued that information science research focused too heavily on how library systems present sources to users, neglecting the users' perspective. To address this gap, Kuhlthau developed the Information Search Process (ISP) model to define the stages of information seeking through a cognitive lens. This model described the thoughts and feelings that students experience when researching a new topic. Confusion and uncertainty define the early stages, eventually moving toward clarity and confidence by the end of the process, mirroring the learning process. Importantly, this movement is not linear; Kuhlthau emphasizes that once students begin to find sources, confusion and uncertainty can increase—students tend to become more frustrated than before they began searching, and this frustration can cause them to abandon the effort.

A significant source of confusion for many students is their unfamiliarity with academic databases. Reference librarians—a valuable resource when utilized—can point students to field-specific academic databases with the capability to narrow searches to peer-reviewed works, but a 2015 EBSCO survey of 208 undergraduate respondents showed they were almost twice as likely (58 percent) to approach their professor for help researching an assignment as they were a librarian (32 percent) [3]. The majority of respondents (54 percent) said that their library website was "challenging" or that they had never used it, and they were unfamiliar with search terms like "database," "Boolean," and "full text." Respondents who did access databases preferred basic searches (71 percent) to advanced searches (23 percent) [3].

Students sometimes prefer to forgo academic databases altogether. A study by Mbabu et al. [4] found that only 42% of the undergraduate student participants ranging from freshmen to seniors accessed a scholarly database at all during the semester in which the study took place, with freshmen and sophomores more likely to do so than juniors and seniors, despite the latter taking more advanced-level coursework. Mbabu et al.'s research also explores and reinforces prior studies establishing that college students favor general web searches over the use of academic databases [4].

Today's undergraduates are likely conducting much of their research outside the boundaries of academic databases, and their teachers may choose to narrow and restrict their students' search

parameters (e.g., requiring students to use only peer-reviewed journals), or they may choose to meet students where they are: searching the internet.

Advantages and disadvantages of a "peer-reviewed sources only" approach

Teachers may limit students to using peer-reviewed sources to boost source quality. While this approach has benefits—namely, it is a seemingly quick, straightforward way to raise scholarly standards—it creates some potential pitfalls. While academic databases can help students narrow their searches to high-quality sources, closer examination shows that these indexes themselves have benefits and drawbacks.

Scopus (scopus.com), for example, is one frequently patronized indexing database, created in 2004 and owned by Elsevier. Likely few would argue that Scopus is a valuable research tool: it includes abstracts and citations for journals, books, conference papers, and awarded grants representing 240 disciplines [5]. Scopus's Content Selection and Advisory Board (CSAB) consists of 17 "subject chairs," an international panel of various subject-area experts who determine the resources that will be indexed in the database. The list of CSAB members is published on the Scopus website, as is the list of sources included (and a list of sources removed) from Scopus, with the stated goal being "transparency" [5, "How stringent are..."]. The Scopus journal database is updated and culled annually; 141 academic and science journals were newly approved to be added to Scopus in December 2022 alone [5]. The site also shows users helpful metrics like a journal's acceptance rate and publication time (the time from which an article is accepted for publication until the time when the article is published on the journal's online site—sometimes as little as a matter of weeks), and Scopus includes some open-access journals, with full articles accessible freely through the site. Journals may be added or removed from the list based on criteria such as the regularity of their publication schedules, online availability, transparency regarding their editorial and ethics policies, and—perhaps most critically—citedness [5]. Scopus lists metrics like CiteScore™, Impact Factor (published annually by Clarivate Analytics), and h-index scores for whole journals, individual articles, and authors, respectively.

However, if teachers require students to patronize Scopus (or a similar academic database), perhaps it is also incumbent upon those teachers to disclose the tool's drawbacks. As Yang and Meho [6] noted in their comparison of popular search databases Scopus, Google Scholar, and Web of Science, debate has long existed about using citedness as the main distinguisher of a work's (or author's) value. Yvonne Masters, the editor-in-chief of the *International Academic Forum's Journal of Education* (itself a Scopus-indexed journal), has asked, "why the hype about Scopus?" [7, para. 2]. Masters stresses that metrics built upon citedness disadvantage researchers and journals in newly emerging fields, noting that the minimum time for a new journal to be considered for Scopus indexing is at least two years.

Furthermore, open-source journals have criticized large indexing databases like Scopus for being elitist and the equivalent of monopolies. In *The Guardian* Jon Tennant called Elsevier "corrupt" [8, para. 1] for its "anti-open business practices, high and ever-increasing prices, and dangerously powerful size as a commercial publisher" [8, para. 7]. Tennant described a backlash occurring in academia against Scopus's parent company, Elsevier:

> This profoundly anti-competitive practice has created a dysfunctional scholarly publishing market, and a budget crisis for university libraries. We are seeing national boycotts of Elsevier and rejection of Elsevier journal bundles. Just recently, Swedish and German research institutes announced that they were cancelling all Elsevier subscriptions due to concerns about sustainability, unfair pricing arrangements and a general lack of value. [para. 7]

Outside of Scopus and Elsevier, Jalalian has warned that index factors can be faked or easily manipulated by predatory companies [9], so teaching students to rely on these criteria alone to evaluate a source's value can be problematic.

Perhaps more importantly, a pedagogical approach to source evaluation that only teaches reliance on academic databases may be misguided. If a goal of STEM education today is helping students not only find sources, but also ascertain their quality, then limiting students' searches to sources that have already been through a stringent vetting process is counterproductive.

Advantages and disadvantages of broadened research parameters

This paper's authors argue that teachers should allow their students to expand their research beyond the confines of peer-reviewed scholarly works to encompass mass media, including broadcast media (i.e., television and radio), print media (i.e., print-based newspapers and magazines, as well as their electronic versions), and online media like websites and videos.

One of the main benefits of allowing students to use mass media sources is timeliness. In 2021, Runde [10] studied publication turnaround times (from time-of-acceptance to time-of-publication) for 82 journals in fisheries science and found that, of the 83,797 individual papers included in Runde's study, the "median times to acceptance ranged from 64 to 269 days and median times-to-publication ranged from 79 to 323 days" ["Results"]. For times-to-publication, "the middle 50% [of articles in the study] often spanned a range of 100 days or more. Distributions were typically skewed right. Virtually every journal in the study published one or more papers that took close to 600 days to publish (the maximum timespan retained in the analysis)" ["Results"]. Contrastingly, broadcast and print media excel in the rapid dissemination of information, and in today's interconnected society, an online media story can circumnavigate the globe with a click on a keyboard, yet mass media sources are sometimes dismissed as sacrificing quality for speed.

Perhaps the greatest challenge—and greatest benefit—of teachers allowing students to incorporate mass media sources is that students have an opportunity to encounter mis(dis)information or biased information and, therefore, to build information literacy skills.

Once students find sources, they must overcome their next hurdle: evaluating those sources. The aforementioned 2015 EBSCO survey found that 41 percent of survey respondents said that their top difficulty was "evaluating the best resources for my paper" [3, "The Research Experience"]. A 2000 study by Burton and Chadwick [11] asked undergraduate college students to rank a list of criteria they used to evaluate sources when writing a research paper. Of 23 criteria to choose from, students ranked "source is available" highest, followed closely by "source is understandable" and "source is easy to find" [11, Table 6]. They also prioritized current sources,

choosing “source contains up-to-date facts” and “date of publication” as important criteria. In contrast, the criterion “source is cited by others” was less of a priority (14/23), and “source is peer reviewed” was near the bottom of the list (21/23) [11, Table 6].

Burton and Chadwick also asked students about the instruction they had received in evaluating sources. While 57% of students said they had some library instruction, most reported that they only received instruction in high school; only 27% received any instruction about source evaluation in college. Students were also asked whether they received any training in evaluating internet (non-library) sources. Only 33% of students had received any instruction in evaluating internet sources, and the highest percentage (17%) said that their only instruction came from a peer, not from an instructor or librarian [11, “Training of students”].

Perhaps never before has such instruction been so critical for students. College students are currently weathering what has been termed the “Misinformation Age” [12] or an “infodemic” [13]. The ways in which the U.S. (and other societies) consumes media have changed [14]. Kuhlthau’s [2] warning about conflicting and inconsistent information is especially relevant today, with the rise of misinformation and increasing reliance on social media for news [15]. It is understandable that students would feel uncertain and confused about where to turn for reliable information—and equally understandable that instructors would struggle with how to guide them [16].

The following sequence of discussion- and writing-based exercises was developed by technical writing instructors in Mississippi State University’s Shackouls Technical Communication Program (STCP), housed within the James Worth Bagley College of Engineering, which encompasses eight engineering departments. These exercises are designed to walk students and instructors through the source evaluation process. Although each activity has a distinct purpose, the overall goal is to prompt students to think critically about different types of sources and to reflect on how they can apply what they are learning.

Discussion-Based Exercise #1: Distinguishing among different types of media sources

To counteract misinformation and identify source bias, one way in which teachers can help their students is by beginning with a two-part class discussion about mass media types and regulations. This exercise, provided in two parts, can be completed in one to two 50-minute class periods, depending on the length of class discussion that the teacher encourages.

Part I: Establishing that various types of mass media are regulated differently

The teacher may begin this exercise by having each student bring in or submit a media article related to one topic (assigned by the teacher or, ideally, chosen by the class.) These sources should preferably represent the three major types of mass media: broadcast, print, and online—particularly social—media. The class may then sort these articles into the three categories while the teacher prompts class discussion.

PROMPT: What do we know about these types of news sources before we even begin reading?

Students may present a host of answers—or none at all—but one correct answer is that these three types of media are regulated differently.

Of the three aforementioned broad categories of mass media (broadcast, print, and online), broadcast television stations and AM, FM, and Low Power FM radio are the most regulated because they rely on broadcast signals and public airwaves and, therefore, are regulated by the Federal Communications Commission (FCC), as established by the Communications Act of 1934.

While the lay person may associate the FCC only with sanctioning TV and radio licensees for obscene or lewd programming, the FCC is also tasked with a key role in safeguarding information literacy and free speech. First, the FCC discourages misinformation through its "hoax" and "distortion" policies. Licensees are not allowed to broadcast hoaxes without a disclaimer, meaning they cannot broadcast information related to a "crime" or "catastrophe" if the licensee knows the information to be false or knows that the information may foreseeably or directly harm public health or safety or divert emergency services (readers will recall the infamous "War of the Worlds" radio broadcast that sparked public panic in 1938), nor can they participate in distortion, in which licensees "can be proven to have deliberately distorted a factual news report," though the FCC notes that "[e]rrors stemming from mistakes are not actionable, nor are expressions of opinion (however unsubstantiated they may seem to some viewers or listeners)" [17, "What is the FCC's responsibility?"]. Furthermore, the FCC ensures that its licensees meet their legal duties to disclose "sponsorships," informing their audiences of potential conflicts of interest. Finally, the First Amendment prohibits the FCC from practicing censorship, and the FCC protects the rights of its broadcast licensees to ensure that "the most diverse and opposing opinions will be expressed, even though some views or expressions may be highly offensive," as long as those views "do not involve a 'clear and present danger of serious, substantive evil'" as established by the Constitution [18, "What is the FCC's responsibility?"]. The FCC's responsibility includes actively protecting and encouraging open public discourse and the circulation of dissenting opinions, helping thwart the confirmation bias that can take root when audiences find themselves in an information echo chamber. The FCC's jurisdiction generally does not extend to non-broadcast media, such as subscription-based cable and satellite TV and radio stations, print-based media, and online or social media.

U.S. newspapers (whether they appear in print or electronic versions) are less regulated than broadcast stations in that they do not fall under FCC licensing and control. However, newspapers and magazines are legally considered publishers and are liable in court for the content they print (with some exceptions for letters to the editor). Even within the broad category of print media, distinctions exist: for example, certain legal transactions require public notice and must be published in newspapers of general circulation or newspapers of record.

Currently in the U.S., social media sites like Facebook and Twitter are considered "platforms" instead of publishers and are therefore the least regulated of the three types of media. These platforms are legally shielded from lawsuits about user-posted content (with some exceptions) under Section 230 of the Communications Decency Act. Debate about whether these social

media sites truly constitute platforms or should be considered publishers is ongoing, and teachers may wish to prompt discussion in their own classes.

PROMPT: Share your opinions about whether social media platforms constitute "platforms" or should legally be defined as "publishers." In other words, should Section 230 be revised?

In discussing the perils to societies—not just in the U.S., but globally—of allowing online or digital news sites to perpetuate disinformation, Darrell M. West of the Brookings Institution also highlights the dangers of legally regulating such sites, as he explains that Indonesia, the Philippines, and Germany have done. West warns that overcorrection of such sites could threaten democracies: "Overly restrictive regulation of internet platforms in open societies sets a dangerous precedent and can encourage authoritarian regimes to continue and/or expand censorship" [19, "The Risks of Regulation"]. West proposes that using the same algorithmic technology that can spread misinformation to instead flag it would help provide greater accountability for the sites most prone to posting misinformation (listed in [20]), and West also argues in support of real-name registration, in which social media users must register their social-media accounts using their verified identifies, providing greater accountability measures against libel, slander, or hate-speech posts.

Part II: Screening mass media sources for inaccurate and/or biased information

When students incorporate mass media sources into their work, the task becomes much more complex than distinguishing factual from fake news—although this is certainly a concern. Additionally, however, students will likely encounter sources with varying degrees of credibility and/or bias, requiring a nuanced decision-making process. In a 2019 study of undergraduates who were asked to distinguish real from "fake" news stories (stories that had been debunked on sites such as snopes.com), students correctly identified 64% of fake news and 60% of real news stories. The students who performed better demonstrated more advanced critical thinking skills [21]. Bias is a consideration because much of mass media is commercial—grounded in business—and businesses need money to survive. Mass media companies have owners and investors to whom they are accountable financially and otherwise. At this point, teachers may test students' knowledge of "big name" owners of mass media outlets.

PROMPT: Name a "celebrity" who owns the majority share of a newspaper, magazine, or social media platform.

Students will likely immediately identify Twitter as being majority owned by Elon Musk, but the *Washington Post*, *The Atlantic*, and the *Wall Street Journal*—as a few more examples—are majority owned by technology or media moguls such as Amazon's Jeff Bezos, Laurene Powell Jobs (the widow of Apple's Steve Jobs), and Rupert Murdoch. This list is hardly exhaustive.

This is not to say that these owners have invested in news media companies for nefarious purposes or that these publishers/platforms and their boards and employees are generating self-serving content. Rather, Bezos has said a key reason he bought the *Washington Post* is to preserve the sanctity of its reporting [22]—although *Forbes* has somewhat pessimistically

termed Bezos and proclaimed like-minded owners as "philanthropic white knights" [23, para. 2]. But it is worth noting to students that media content is created by people, who may need—if not from a legal, at least from an ethical standpoint—to disclose conflicts of interest or work to counteract their own intrinsic biases. Class conversations about media ownership are also worthwhile. As Heidi Legg with Harvard's Future of Media Project asks, "If information wants to be free and journalism is about shining light and offering readers context, it is then in the service of journalism to understand who owns our media outlets: What is their reach? Who is making money or benefiting from a particular lens?" [24, para. 1].

These questions are valid: who *are* these people? However, it is important to acknowledge that much of today's content is *not* actually generated by people, but rather by bots.

Discussion-Based Exercise #2: The rise of chatbots and natural language processing (NLP) models

Hidden within mass media sources are social bots or automated accounts used to spread misinformation online and make posts on social media appear more popular than they really are. Shao et al. [25] studied this phenomenon across Twitter during the US presidential campaign of 2016, confirming bots were responsible for making "low-quality information" [p. 3] easily available and attractive to others to share it. Shao et al. also suggest that viral posts are typically the result of bot intervention immediately after an article's posting.

Bots are not the only perpetuators of misinformation. Leeder found that students' "willingness to share news stories was unrelated to trustworthiness evaluations" [21, Sec. 5.1]. This finding might help explain a 2018 study showing that false information on Twitter was retweeted by more people and more quickly than accurate information [15].

Student access to NLP models such as ChatGPT also complicates instruction in both writing and source evaluation. ChatGPT is OpenAI's free, artificial intelligence-based software released on November 30, 2022. It takes questions or requests from users and provides responses that mimic human writing. Today's AI-generated content is sophisticated; *Nature* reported that scientists surveyed were unable to identify content as being written by an AI generator [26]. Educators are now pondering how to incorporate ChatGPT or attempt to ban it entirely from the learning environment.

Two basic questions of authorship arise, the first being *who—or what—has written this content*? A few tools in their early stages may be useful to track AI-written material. GPTZero is one such tool used to identify AI-generated material. GPTZero is said to evaluate passages based on "perplexity" and "burstiness" [24; para. 8]. Bowman [27] explains,

> Perplexity measures the complexity of text; if GPTZero is perplexed by the text, then it has a high complexity and it is more likely to be human-written. However, if the text is more familiar to the bot—because it has been trained on such data—then it will have low complexity and therefore is more likely to be AI-generated. [para. 8]

Burstiness equates to difference in sentence length; whereas "humans tend to write with greater burstiness," AI writes sentences that match in length [27; para. 8]. Furthermore, Scott Aaronson,

a researcher at OpenAI, is currently attempting to develop a type of watermark for AI-generated text [28].

The second question is, *who—or what—is vetting the information within this content?* Educators will have to contend with how ChatGPT and its competitors (like Google's Bard) shape the information literacy landscape. OpenAI admits on its website that ChatGPT "may occasionally generate incorrect information; may occasionally produce harmful instructions or biased content" [29, Limitations]. This disclaimer's repeated use of the vague descriptor "occasionally" and its references to harm and bias demonstrate why educators are understandably concerned about students unsuspectingly perpetuating false information. Bard, meanwhile, embarrassingly generated a factual error in its 2023 public debut when it wrongly claimed that the James Webb Space Telescope was the first to gather images of an exoplanet, which NASA refuted [30].

A battle to discourage students from using AI-based content entirely would likely be futile: ChatGPT vigorously surpassed one million users within a week of its launch, tweeted OpenAI CEO Sam Altman [31]. Almost a third of college students polled in a 2023 survey admitted to having already used ChatGPT for assignments [32]. *The Stanford Daily* reported that 17% of Stanford students surveyed had used ChatGPT for exams or assignments during the fall 2022 semester [33].

These numbers are concerning given ChatGPT's current limitations, among them technical limitations. The software is currently trained only on data through the year 2021, it is particular about phrasing of input, it sometimes "guesses" user intent based on queries, it uses certain phrases excessively, and it refuses some requests as "inappropriate," OpenAI discloses on its website [29]. In addition, it cannot support content with in-text citations, but it can be prompted to fabricate source material and, when asked if it wrote certain material, may give an evasive or dishonest answer, as this paper's authors have experienced. Educators have reported limitations including that ChatGPT is incapable of reflective writing or making substantive comparisons between ideas [34].

One way colleges may attempt to curb AI-generated content submitted by students is by requiring honesty pledges on submitted assignments. A 2023 survey by Intelligent revealed that of 1,000 U.S. college students 20% believed using ChatGPT is not considered cheating [35]. Other educators are revising current assignments to make them more AI resistant. Teacher and author Anna Mills and Lauren M. E. Goodlad, the editor of *Critical AI*, recommend that teachers begin by informing students that AI-detecting software is being refined and could be used to identify plagiarism. When developing writing prompts, teachers should consider which prompts AI systems have difficulty handling. Such assignments might require students to "verif[y] sources and quotations; analy[ze] specifics from images, audio, or videos"; read and decipher texts that are too long to fit in the text box provided; require analysis from more current events that the system has yet to be trained on—events after 2021; or require assignments that are based on subtle relationships between two or more ideas or texts [34; para. 7]. Another strategy is to connect writing to in-class activities, assigning students to write a response to a class discussion or giving them class time to start their writing assignments [34].

In thinking about the implications of NLP models for source evaluation, Qadir [36] cites Toyama's concept of technology's law of amplification, which states that technology itself is neither good nor evil; it only amplifies human intentions [37]. In a matter of years, NLP models may be ubiquitous. The topic lends itself well to class discussion.

PROMPT: Do ChatGPT and its competitors have a place in academia and/or the workplace, and if so, what do you think it is?

Applying technology's law of amplification to NLP models like ChatGPT, education is key to minimizing misuse, specifically teaching students how to think critically so they can analyze the benefits, risks, and ethical application of these tools [36]. By asking students open-ended questions about the implications of ChatGPT and acknowledging that much is still unknown, instructors can demonstrate that *any* new technology should be scrutinized; asking questions and considering consequences are exercises in ethics and responsible research, even if no clear answers are found.

Source evaluation pedagogy and techniques: Vertical versus lateral reading

While formal instruction from educators has been shown to improve students' ability to identify and incorporate credible sources [11], best pedagogical practices have shifted in response to the overwhelming array of digital resources students must navigate. This section contains background on vertical and lateral reading techniques, culminating in writing-based exercises that call for students to employ these techniques as a means of navigating web-based news sources.

Instructor background: Understanding vertical versus lateral reading

Vertical reading strategies guide students to look through the source document itself for clues on source evaluation [38]. Traditional source evaluation focuses mostly on vertical reading strategies, requiring students to use their critical-thinking skills to evaluate the source and recognize characteristics of credible, trustworthy information.

A widely used vertical reading method is the CRAAP test. In 2004, Sarah Blakeslee, a research, instruction, and outreach librarian from California State University, coined the term CRAAP—*currency, relevance, authority, accuracy,* and *purpose* [39]. As Blakeslee noted, the acronym "captures the students' attention" during lecture and helps students and teachers remember the criteria and apply source-evaluation techniques [39, p. 7]. Fig. 1 shows a more thorough breakdown of each criterion.

Fig. 1. CRAAP acronym explained [40]

C	**Currency**: ***The timeliness of the information.*** • When was the information published or posted? Revised or updated? • Does your topic require current information, or will older sources work as well?
R	**Relevance**: ***The importance of the information for your needs.*** • Does the information relate to your topic or answer your question? • Who is the intended audience? / an appropriate level?
A	**Authority**: ***The source of the information.*** • Who is the author/publisher/source/sponsor? • What are the author's credentials or organizational affiliations? • Is the author qualified to write on the topic? / contact information?
A	**Accuracy**: ***The reliability, truthfulness and correctness of the content.*** • Where does the information come from? / supported by evidence? • Has the information been reviewed or refereed? • Does the language or tone seem unbiased and free of emotion?
P	**Purpose: *The reason the information exists.*** • What is the purpose of the information? Is it to inform, teach, sell, entertain or persuade? • Does the point of view appear objective and impartial? • Are there political, religious, institutional or personal biases?

The CRAAP test and similar "checklist" approaches can be a useful tool to help students recognize surface-level clues for determining whether to trust a source. Importantly, students should recognize how to integrate and use sources from authors with various levels of expertise (such as information from a journalist versus a university researcher). The CRAAP criteria can also be used to emphasize the difference between scholarly, peer-reviewed articles and popular internet sites, and instructors using the CRAAP test can help students self-identify the importance of using sources that are timely and correct, among other important attributes.

However, the CRAAP test has been criticized as simplistic, especially in today's digital environment. In 2004, Meola argued the checklist poses questions that students might not be equipped to answer, and "this mechanical way of evaluation…is at odds with the higher-level judgment and intuition that we presumably seek to cultivate as part of critical thinking" [41, p. 338]. In a study that contrasted undergraduate students' abilities to recognize potential bias and misinformation with those of professional fact checkers, Wineburg and McGrew [38] found that 64 percent of 25 undergraduates surveyed trusted information posted by the controversial American College of Pediatricians after confusing it with the more established, mainstream American Academy of Pediatrics. Conversely, 100% of the 10 professional fact checkers in the study spotted the distinction between the two sources, all within a 45-minute time limit.

To help combat misinformation disguised as a trustworthy source, professional fact checkers employ "lateral reading," where they investigate the site by opening new tabs and evaluating the source using outside information. According to Wineburg and McGrew, professional fact checkers pay little attention to if the website looks "professional, free of typos, quote[s] well-known sources, [or employs] bias or faulty logic." Instead, "they investigated a site by leaving it… Fact checkers relied on a robust knowledge of sources to inform their decisions" [38, p. 38]. For example, lateral readers might search a particular author to see if the author has published elsewhere, or they might research an organization to see if there is a potential bias at play. Furthermore, lateral readers do not take quotes in an article at face value; instead, they search for the original publication, double-checking the information across different sources and ensuring that it is used properly. Leeder [21] also specifies lateral reading as a standard practice students should be encouraged to use as part of any research process, noting that this habit will make students more discerning consumers of information in general, not just in the classroom.

Meola's suggested lateral reading approach [41] is to teach students about peer and editorial review, guide them through in-depth comparisons of web-based and peer-reviewed sources, and help them understand what corroboration means. This method has been effectively incorporated in STEM courses, including a physics class [42]. However, instructors have noted that this approach requires more in-depth, time-consuming class instruction than a checklist [43].

A different type of checklist was developed by Caulfield [44] in 2017. Described as a series of "evaluative moves" that instruct students to take specific actions when examining a source, this method was designed to approximate the techniques of professional fact checkers. These four moves are "*Stop, Investigate the source, Find better coverage, and Trace claims and quotes to their original source (SIFT)*" [44, Fig. 1]. Notably, the critical thinking involved in these moves is similar to Meola's approach and also requires lateral reading, but the moves are articulated as direct actions, with an easy-to-remember acronym similar to the CRAAP test.

Building on this idea, Rumble et al. suggest that instructors introduce the concept of "information need" [45, p. 163] to students as they practice lateral reading, which is the idea that different types of sources (e.g., journal articles, books, newspapers, and websites) might be more appropriate depending on the research scenario. Through small-group, discussion-based activities, students were asked to compare their findings for the same search terms using different categories of sources. Rumble et al. further emphasize that these activities do not have to be tedious and can even be designed as games, framing "searching as strategic exploration" and connecting the process to the critical-thinking skills that students develop throughout college [45, p. 165].

The following writing-based exercises are designed to teach students both vertical and lateral research techniques. By contrasting the two techniques, students can fully grasp both and see different situations where a variety of evaluation techniques can be useful in rooting out misinformation. Each activity is designed to take place in 50 minutes or less.

Writing-Based Exercise #1: A combination of vertical and lateral reading

This activity is designed to emphasize the difference between vertical and lateral reading by explicitly requiring students to conduct both types on two different sources—e.g., one representing a more conventionally credible, objective source and the other demonstrating a bias that requires more caution and skepticism. Typically, instructors can provide all students access to the same sources for evaluation. Suggested source comparisons are the American Academy of Pediatrics (aap.org) and the American College of Pediatricians (acpeds.org), as Wineburg and Mcgrew used in [38].

Writing-Based Exercise #1: "Vertical" and "lateral" source evaluation

Directions: Start by analyzing both Source A and Source B in a "vertical" fashion. Afterward, switch to a "lateral" evaluation technique and see if your answers remain the same.

1. Start by "vertically" evaluating both sources, searching within the documents for clues on their credibility. Consider using the CRAAP test to guide your responses. Is the author listed, and is that author credible? Are the sources within the article cited? Is it free of grammatical errors or other potential red flags, such as an abundance of advertisements? Does it have a more informational or argumentative tone? Overall, does this source pass the CRAAP test?

    A. Search vertically for Source A:

    B. Search vertically for Source B:

    C. Of the two sources, which seems the most credible using only vertical search techniques?

2. Move to a "lateral" reading of the sources. Exit the documents, open new tabs, and search for the organization/author. Does the source appear objective? Does a search of the author/organization reveal a potential bias? Check any quotes or facts presented in the article by finding the original publication: does it match, or is there a misuse/manipulation of sources?

    A. Search laterally for Source A:

    B. Search laterally for Source B:

    C. After searching laterally, which source seems the most credible? If your answer changes from the vertical search, why? If it's the same, how does this justify your previous stance?

3. Briefly state the difference between vertical and lateral reading. How might using a combination of both impact your future research techniques?

Question 1 requires that students first apply criteria from the CRAAP test for evaluation of both sources. They should practice valuable techniques such as checking publication dates, references, grammar, and so forth. In this way, students get practice in vertical reading, helping emphasize the differences (e.g., timeliness of the source) in scholarly sources and popular sources.

In Question 2, students are required to take their source evaluation a step further. Rather than rely on the source itself for information, students open new tabs and search across the internet to determine credibility. They might search for the author or organization, or they might check facts by finding the original references and source material. Here, students differentiate lateral reading from vertical reading, and they gain some practice in applying internet searches for source evaluation.

In Question 3, students reflect on their practice and write about how this exercise might impact their own searches. By explicitly analyzing and reflecting on their own research habits, students are probably more inclined to adopt both vertical and lateral search techniques.

Writing-Based Exercise #2: "Professional" fact checking for your peers

This activity requires that students act as "professional fact checkers" for their peers. Typically, this activity is useful during a drafting process for a paper, after Exercise #1 has been completed and students have begun writing their own papers.

Writing-Based Exercise #2: Fact-checking activity—Evaluate your partner's source use!

Directions: For this exercise, you'll choose at least one of your partner's main sources. Afterward, you'll act as a "professional fact checker," evaluating both the credibility of your partner's sources and their use of those sources. Remember that fact checkers go outside of the original article, opening new tabs to discover information about the article/author.

For this exercise, "author" refers to the author of the source in question. "Partner" refers to the student pairing for the exercise.

1. What is the author's background? Go outside the source to see if they've published elsewhere. Are they a journalist? A STEM subject matter expert? What qualifications and/or credentials do they hold? How might the level of expertise impact how your partner uses the information?

2. Check the process in which the source is held liable for misinformation. Is it print media, such as a newspaper or magazine? A non-subscriber-based news broadcast? Peer reviewed? Or is it a (largely) unregulated social media/blog post?

3. Using both the author's background and the author's use of sources, evaluate potential bias. Is this source mostly argumentative, or it is mostly informational? How might this distinction impact your partner's use of the source?

4. Verify the author's work by checking the in-text citations. Go outside of the text and open a new tab. Can you find any quotations in the original context? Are these quotations/claims verifiable? Faithfully representative of the original author's intent?

5. Evaluate your partner's use of the source. Did they adequately communicate the credibility of the source in question? Were they accurate in their summary of the source in question?

6. How might this activity impact your own source use? What techniques can you use to ensure that you're using sources in appropriate ways?

Because Exercise #2 requires students to act as professional fact checkers, it provides a chance for students to apply the SIFT process proposed by Caulfield [42]. Thus, students practice lateral reading on a peer's draft, checking both the source cited and their peer for proper source use.

Questions 1 through 3 begin the "Stop" and "Investigate" portions of SIFT. "Stop" asks that students pause for a moment and consider the nature of the document before trusting the information. The "Investigate" portion asks that students consider the background of the source itself. According to Caulfield [44], "[Fact checkers] open up many tabs in their browser, piecing together different bits of information from across the web to get a better picture of the site they're investigating. Many of the questions they ask are the same as the vertical readers scrolling up and down the pages of the source they are evaluating. But unlike those readers, they realize that the truth is more likely to be found in the network of links to (and commentaries about) the site than in the site itself" [Sec. 16, para. 6]. In other words, students walk through the process of evaluating the credibility and potential bias of a source.

Question 4 entails the "Trace" portion of SIFT. Here, students look at the quoted or paraphrased information cited in the source and find the original. As such, they ensure that the source in question accurately represents the original work of other sources. They also gain knowledge about the topic, allowing for a more informed and thorough overview of the subject.

Questions 5 and 6 are more holistic and reflective in nature. Question 5 ends the lateral reading of the source with an overall evaluation of a student's partner's use of the source. If the source is credible and usable, this step ensures that the partner has adequately and accurately communicated the credibility of said source, ensuring strong source use. Question 6, then, connects the activity to the student's own source use and hopefully ensures that the lateral reading techniques carry over to the student's own research.

Writing-Based Exercise #3: Self-evaluative source workshop

Exercise #3 is the culmination of the source workshop. Here, students combine their techniques of vertical and lateral reading to evaluate their own source use, ensuring that they incorporate these classroom lessons into their own research habits. This exercise can be done in a 50-minute class period if students bring their own drafts. Alternatively, it can be assigned as homework.

Writing-Based Exercise #3: Self-evaluative source workshop

1. Begin by analyzing the author and checking information outside of the source itself. If an author is listed, try searching for other articles that the author wrote. If there is no listed author, try looking at the organization. What is the organization's background? Is there any perceived bias? Does it appear objective?

2. Check the sources the article uses by exiting the source and searching outside of it. If it is electronic, try "lateral searching." Can you find other legitimate sources to corroborate the information? Try looking up any sources that the author lists. Do they appear legitimate? If there are no sources, are there any questionable claims that need sources? How might this affect how you use the source?

3. Write a brief summary of the source. What is the overall goal/objective of the article? Is it more informative or persuasive? What are some of their main points? What types of evidence does the article use?

4. Identify one important piece of the article that you might use and quote it in APA/IEEE/etc. style. Try using the "research tags" that we discussed in class.

5. Try paraphrasing one important piece of the article that might be useful for your project. When paraphrasing, remember to put the sentence into your own words (and sentence structure) while including an in-text citation.

6. Briefly summarize how you might benefit from this source. What will you use it for?

Questions 1 through 3 require students to use both vertical and lateral search techniques. While knowledge of the CRAAP test is useful in these questions to evaluate the credibility of the author and their evidence, the questions also ask that students employ lateral reading by exiting the document and finding the information elsewhere. This step is also useful as it allows students to find more sources and gain a wider knowledge base.

Questions 4 through 6 ask students to begin writing about their source. Here, students are required to use a "research tag," where students lead into a quote by giving information about a source's credibility (such as saying, "According to a *New York Times* column" or "According to researchers from the University of..."). In this manner, students are taught to be a responsible

author themselves by communicating to readers the source author's credibility and level of expertise, thus encouraging readers to apply their own judgment to the source. The final question helps students recognize that different sources, with authors of varying backgrounds, can be useful for different parts of a paper. For instance, an article from the *Wall Street Journal* might be appropriate in discussing the price of a project such as a maglev train. Alternatively, a scholarly, peer-reviewed source might be more useful for discussing the functionality and efficiency of such technology.

These exercises are designed to reinforce both vertical and lateral reading, helping students relatively quickly and painlessly become more well-rounded researchers. While Writing Exercise #1 separates the two types of reading to help students understand the intricacies of both, Writing Exercises #2 and #3 combine the two types seamlessly, thus guiding students to become more efficient, focused researchers.

Findings and future work

This paper's authors have so far run limited evaluations of these activities' effectiveness but through anecdotal experiences have found them to be valuable exercises in the classroom. While the findings show promise in encouraging students to expand beyond traditional source evaluation techniques, more qualitative and quantitative data collection is needed. This work would lend itself well to student and instructor interviews, questionnaires, and surveys, as well as evaluation of samples taken of students' work throughout the semester.

The following sample reflection is provided by an instructor after integrating "vertical" and "lateral" source evaluation lessons into GE 3513 Technical Writing classes at Mississippi State University, classes populated almost entirely by junior- and senior-level undergraduate students representing eight engineering disciplines.

Instructor reflection (John Aaron Grimes)

After years of discussing only traditional, vertical source evaluation, I have expanded my instruction to include more lateral search techniques to help prepare my students for navigating source evaluation across different mediums. After using Writing Exercise #1 as an activity in my classes, I informally polled students to see how many could identify a source that was displaying bias.

I began by reminding students of the CRAAP test parameters. Students then employed vertical search techniques to evaluate information from the American College of Pediatricians compared to that from the American Academy of Pediatrics. This pairing of sources was gratefully borrowed from Wineburg and Mcgrew [38] in their work evaluating the techniques of professional fact checkers. Among my students, 12 out of 41 students (29 percent) initially labeled the American College of Pediatricians as a credible source based on vertical evaluation, saying that they would use it in their own papers.

I then reminded students about lateral search techniques. Students researched on their own and conducted lateral search techniques for approximately 10 minutes. After the lateral test, only 1

out of the 41 students found the American College of Pediatricians source to be credible. While the majority (71 percent) of students had correctly flagged bias in the American College of Pediatricians source strictly based on vertical reading, the remaining 29 percent had found the source credible upon first impression. After my classes implemented a lateral reading, however, this percentage dropped to just 2 percent of students. Class discussion revealed that the students were able to learn more about the history of the American College of Pediatricians from lateral searching. For many students, this search helped them recognize biases.

To expand on the informal poll, I asked students to respond to the following written prompt: "Briefly state the difference between vertical and lateral reading. How might using a combination of both impact your future research techniques?" The following excerpts from student responses demonstrate the value of teaching both vertical and lateral search techniques in the classroom:

Student Response #1: "It really helped me to see things differently because it shows more about their motives and biases when you check a source laterally. I will still be checking a source vertically first, but by incorporating lateral reading I can make sure to pick the source that most effectively works with my papers."

Student Response #2: "Vertical reading cannot be solely trusted to support a document because it is easy to hide a source's true credibility. Lateral reading allows you to go through and do a bit of background information on a source to know whether you can really trust it. You can use a combination of these techniques by vertically reading an article to help with finding information about a topic and then using lateral reading to help you determine whether that source would be a credible one or not."

Student Response #3: "Vertical reading is analyzing the document/source/website itself to determine its general credibility at face value. Lateral reading is analyzing the source from the POV of outside websites and information; it's a deeper dive. You can learn more about the credibility of a source through lateral reading by determining things such as controversies, blatant political biases, the credibility/correct context of the source's citations, and more. Using a combination of both will impact my future research techniques in that it will allow me to verify a source before usage, strengthening the paper overall."

Student Response #4: "Vertical reading is a quick observation of credibility done by an individual, and it can potentially be deceived by the subject of observation if all things are taken at face value. Lateral reading is a more accurate deep dive into credibility often done by many individuals or groups (often credible sources themselves). Using a combination of the two can be useful as a vertical reading can quickly narrow down possible sources, and lateral reading can validate those sources."

In each of the answers, students recognize the importance of incorporating a variety of source evaluation techniques to identify timely, accurate source content. Based on the results of the informal polling and students' written responses, we are encouraged that these activities can be used to help students gain deeper insight into different source evaluation strategies and become more discerning researchers. At the same time, we recognize that more formal and robust data collection efforts would be required to draw definitive conclusions.

Conclusion

Instruction in source evaluation is not just the purview of a librarian or composition instructor. A particular challenge for today's STEM educators and students is "the variety of information sources and formats that carry the body of knowledge in their field," including patents, government documents, data sets, and multimedia sources [1, para. 1]. Another complexity is the interdisciplinary nature of STEM disciplines, requiring an adaptable approach to evaluating a wide range of sources [46]. It is important to teach (not merely to tell) STEM students to use academic databases or peer-reviewed journals. But limiting students to searching only academic databases puts them in an artificial bubble and hinders their ability to build useful information literacy skills. STEM students will not develop these skills if they never have a chance to encounter misinformation or biased coverage. Mass media news outlets provide important learning sandboxes for students to recognize misinformation or biased information in real time.

Also important is educating students to use AI-based tools like ChatGPT cautiously and ethically—both to skirt academic misconduct and to deter the spread of misinformation. Equally important is to educate them about the ethics of disclosing potential conflicts of interest and to arm them with practical source evaluation methods to seek out misinformation and bias as a critical step of their research process.

As the academic landscape constantly shifts, the new STEM educator has a pivotal role to play in helping ingrain basic skills so that their students can navigate the world as savvy consumers of information.

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