Digital Resources for Students: Navigating Scholarship in a Changing Terrain

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ABSTRACT (ENGLISH)

The rapid growth and change in scientific and other scholarly publications have made it more challenging to find appropriate resources for a research need. This difficulty is further complicated by research articles that target only a specific audience of experts. With a rise in digital technologies, research can be shared in new ways, allowing for novel methods of evaluation and collaboration in the sciences, as well as other disciplines. In this article, the authors describe digital resources to help students and other researchers discover, interpret, and evaluate information. Some resources also promote collaboration and discussion on research topics in a classroom or research group. Students can benefit from library and course instruction that emphasizes how these tools connect with the process of creating new scholarship. Teaching about these resources could also offer valuable opportunities for metacognition and transfer beyond the classroom.

FULL TEXT

Introduction

The current state of information seeking often arises from inquiry-based, yet serendipitous, discoveries. As the scope of scholarly publication rapidly expands, it is a challenge for anyone to keep up with the research. The publication landscape is changing too, offering new options for accessing research, such as before peer review and through social media. Social and digital intermediaries such as Google, Twitter, and Facebook dominate the current media environment.[1] The open science movement, which aims to make scientific research and data accessible to all, has also provided access to information in multimodal formats, where data are shared more readily, sometimes outside traditional publishing venues. These digital points of access offer opportunities for communicating and evaluating research, as well as a chance to immerse students in novel ways of scholarly communication. Students who become acquainted with these methods may become more proficient and cognitively aware researchers.

Students as Researchers

Over the last decade, little has changed about the way students find resources for a task. They rely on instructor recommendations and course material, then use a public source, such as Google or Wikipedia, to find more information. Lastly, they turn to scholarly databases.[2] This means that even though the landscape of information has changed online, students will still follow the familiar techniques for assignments without outside direction. Some students are also unaware that one database may cover one set of disciplines better than another, necessitating that students learn a variety of ways to search for sources, rather than rely on a familiar practice. For example, a study found more representation of publications from a nursing field in Scopus than in Web of Science, though both are subscription-based services with presumably better coverage than a free tool such as Google Scholar.[3] This inconsistency across databases is further complicated by library and institutional access, which is beyond student control or what librarians can teach. As an addition to traditional search techniques and databases, digital tools could help students find newer information in different ways and cite more articles of interest.[4]

Challenges and Opportunities

Early researchers and students face a "cognitive burden" when they begin writing in an academic discipline, unsure of where to start without mentoring and collaboration.[5] Students expect to learn about the process of peer review, publication, and experiential research from their mentors, rather than from librarians or traditional course instruction.[6] Yet, library, writing, and research courses offer a rich opportunity for this conversation. Students use databases and professor recommendations for academic assignments,[7] so librarians and instructors may influence the types of resources they use.

While most students believe that they can find research on any topic, it is more challenging to find information to fit a critical need.[8] In the sciences, evaluating primary research is difficult for students, and even faculty report that reading the literature can be frustrating.[9] Students may not read an article fully before citing it and may fail to understand how the results fit the conclusions.[10] Most undergraduates report reading primary literature to broaden their knowledge or better grasp a topic, rather than to improve their ability to think critically.[11] Given the technicality level of primary research articles, these issues in reading and evaluation are understandable, but they reinforce the need to help students find strategies to improve their skills.

A significant challenge to early researchers and students is evaluating all the research they find in a database search. When students enter a new area of research or topic searching, they may have little or no exposure to the literature at a professional level. Early researchers lack the constant immersion in recent scholarship that comes from conference travel, familiarity with experts in that subject area, and database alerts.

With a growing number of publications and greater access to more articles, there are also notable reproducibility and replicability issues in the sciences. A survey of scientists across disciplines reported that most scientists have failed to reproduce their own experiments or the work of someone else.[12] Collectively, studies have found anything from 20 percent to 75 percent replicability in published works across science disciplines. There is a growing call for stronger reproducibility and replicability in scientific research to both strengthen science and bolster public understanding of science's limitations.[13] Potential solutions to reproducibility include collaborating, sharing data openly, and using social media to enhance teamwork for science that would be impossible to perform on a large scale on one's own.[14] More open data, open access, and open peer review could all provide pathways toward more scholarly transparency,[15] and perhaps more replicable science. At the same time, researchers can use a variety of digital resources to help interpret and evaluate growing research fields as a whole.

Digital Resources and Information Literacy

In the classroom, digital resources may make students more aware of the complexity of the research and publication processes. Such awareness offers an opportunity for deeper metacognition—understanding of one's own thought processes—and increased information literacy. Evaluating a growing body of information aligns with all steps of the research process and metaliteracy.[16] In the role of consumer and producer, a researcher must determine if an article meets the needs of the task, as well as how it compares to other research in the discipline. The researcher uses this knowledge to ask new questions, form hypotheses, and design experiments. Incorporating other scholars' research into a new research project is a metacognitive, collaborative, and reflective task.

In preparing this piece, the authors found several themes that align with the Association of College and Research Libraries Framework for Information Literacy for Higher Education and information retrieval topics.[17] The discovery tools described in this article can be incorporated into course activities that reinforce the Framework. Such resources support the frame "Searching as Strategic Exploration," while collaborative online tools exemplify "Information Creation as a Process" and "Scholarship as Conversation." Applying the Framework helps students connect the literacy skills necessary to perform research. Discovery involves processes related to information retrieval and management. Synthesizing research is a competency that involves higher-order cognitive skills. Critically evaluating and applying the information to solve problems are yet other dimensions of research. Digital resources can support aspects of problem-solving, inquiry, and social engagement in a highly collaborative environment. Collaborative and creative digital skills are also interrelated and positively contribute to problem-

solving skills and metacognition.[18] Students and early career researchers use an array of tools and approaches in their scholarship and research. A desire to problem-solve is a trait attributed to today's students.[19] A multitude of digital resources are available at their fingertips, while algorithmic filters inform inquiry and decisions.

In this article, the authors compile digital resources to help students and early researchers navigate the expansion of scholarship, both in the sciences and in other disciplines (see Table 1). This article will explore digital tools that help students (1) discover new research, (2) evaluate and interpret new information, and (3) collaborate in the scholarly conversation. While the authors have divided the tools into these categories, several tools can help users perform more than one task. Many of these resources are available as websites and browser extensions, and most are free to users at some level. Some of these tools, including scite, PubPeer, and Retraction Watch, are primarily useful across science and health disciplines to address the scientific challenges noted in this article. The second group of resources, such as Kopernio, Hypothesis, and Google Scholar, could be used in library and writing instruction to assist researchers in the sciences, as well as other disciplines, in any career stage.

Resources for Research in the Sciences

Working in the sciences presents researchers with some special challenges, including the rapid growth of scientific research, difficulty reproducing experimental results, and problems detecting retracted data. Worldwide, peer-reviewed scientific publications have grown approximately 3.8 percent annually since 2018 to reach 2.6 million articles. Health-related studies and engineering research, as well as inter-disciplinary work, comprise much of that growth.[20] With an increase in publication has come an expansion in access. It is more common for early researchers (PhD students and postdocs) to approve of open access than not, and PhD students have more favorable views of open access than do professors of all levels.[21] This trend will likely continue because undergraduate science students feel concerned about their future access to scientific research. This section describes digital tools that will help scientists address many of the trends and challenges in scientific research.

Discovering New Research

Preprint Servers

Preprint servers are becoming increasingly common and acceptable across academic disciplines. These servers are online archives or repositories for scholarly papers that have undergone basic screening but have not yet been peer reviewed or accepted by traditional academic journals. Preprints connect research to interested readers faster, before the long peer-review process, meaning that students can find some of the newest research and ideas available on these servers. One new preprint server in the health sciences is medRxiv, pronounced *med archive*, which distributes unpublished manuscripts in medicine and related fields. Publishers and other organizations that maintain preprint servers have considered the ethical concerns of posting pre-peer reviewed content, leading to disclaimers like this on the medRxiv home page: "Caution: Preprints are preliminary reports of work that have not been peer-reviewed. They should not be relied on to guide clinical practice or health-related behavior and should not be reported in news media as established information."[22] While some researchers may be concerned that the articles on preprint servers lack peer review, many of the articles are eventually published in peer-reviewed journals.[23] These preprint servers have exploded in popularity over the years, leading to new servers in almost all science disciplines.

Beyond conferences as an outlet for scholars to announce their findings faster, a preprint is an opportunity to draft and distribute data for both knowledge and open community feedback. Educators can use preprint servers to help students find new scholarship conversations in their field of interest, as well as open discussion about the limitations and prospects of having new research published online, freely available to anyone, before traditional peer review.

Scholarcy

As a free browser extension, Scholarcy helps students decide whether to download and read an article.[24] Scholarcy summarizes research articles and highlights their key points. By simplifying pdfs into chunks of information, this tool provides more information than an abstract for the reader to scan, including specific data points from the article's results section. Though this can be helpful to students who have trouble dissecting a complicated article

on a new topic in any discipline, this is especially helpful in the sciences because it gives a more organized synopsis of the article. Teaching students about Scholarcy should emphasize that it cannot replace analyzing and evaluating an entire research article, but it can help narrow down a large number of articles to those that better fit a writing or research task. After making this choice, a researcher should spend more time assessing the data and conclusions. The website version of Scholarcy offers more functions for students with an individual or institutional license, including the ability to save and export citations and to take notes, and a suggested reading list based on the articles a user saves. See Figure 1.

Evaluating and Interpreting Research

As the use of digital tools grows, these resources can help students recognize the value in a citation. In an age of large data sets, it is an impossible task to analyze all the scholarly publications across a field. Citations can provide information about how data sets interact and suggest ways for the data to work together toward new hypotheses,[25] thereby helping scholars evaluate and interpret related research. The Initiative for Open Citations (I4OC) is a collaboration among academic publishers, researchers, and others to promote the unrestricted availability of scholarly citation data. With the help of natural language processing, open data, and algorithms, academic publishing is moving toward this direction. These initiatives can also help new learners understand larger issues in reproducibility and replicability. For example, students can compare related citations, find open source data, or read a meta-analysis that compares related research.

scite

scite uses a combination of expert training and machine learning, which enables software to learn and improve from experience, to analyze citations in scientific articles. scite then designates these Smart Citations as mentioning, supporting, or contradicting a cited article.[26] Similar to Google Scholar, this classification performs a forward-citation function, which identifies newest articles that cite the one under consideration. The forward-citation function of Google Scholar currently identifies more articles than scite, remaining another convenient way for students to find newer research on a topic. However, scite has analyzed over 600 million citations from 14 million articles to date, with more added daily. These Smart Citations from scite have also started appearing as a citation metric for journal collections, such as Europe PMC (Europe PubMed Central), an open-access repository of medical research literature.

As an extension, scite provides data as a sidebar on every article a user views (see Figure 2). A user who wants to know more about the citation can follow a link to see the context of each citation's text in scite's website. The potential of scite in student research goes beyond helping students discover new citations. It helps learners understand that scientists use citations in various ways and that a heavily cited article may not always be a supported one. A citation might mention previous work in the context of new research, provide evidence of agreement and reproducibility, or contradict and critique the data. While the extension allows users an immediate and cognizant reminder of citations, researchers can also visit scite's website to enter article information and view Smart Citation data.

Connected Papers

Digital tools can help researchers identify related scholarship beyond databases, but it can also help them visualize these connections to evaluate these relationships. Connected Papers uses scholarship indexed in the Semantic Scholar database, covering many science disciplines.[27] After entering a digital object identifier (DOI), title, or database URL, the user sees an interactive node graph connecting cited articles as a web of related citations (see Figure 3). It can help the user identify works that researchers commonly cite in the field, called "prior works," as well as articles that commonly cite the same articles in the graph, called "derivative works." Derivative works may be important forward-citations that build off the work in question. This program can help students visualize a scholarly conversation and interpret the strength of connections between articles in one field.

Retractions

The retraction rate for scholarly articles is relatively low, but it presents issues that students and early researchers might not consider when evaluating information. Retractions can be caused by any error, such as data mistakes,

misconduct, issues with the review process, or conflicts between authors. One study found 1,082 retractions out of over 4 million biomedical papers in PubMed.[28] Approximately half of these retractions were in high impact factor journals, and about 65 percent of them involved misconduct by the authors, mostly through plagiarism and image manipulation. Most of these retractions were initiated by someone other than the authors.[29] Several studies have investigated the reasons behind retractions, often finding a combination of fraud, scientific error, and plagiarism. It takes years to retract a paper, and offenders often "repeat."[30] The issues surrounding retraction present a problem to students because they may see peer-reviewed research as an indicator that the data have been verified by experts. Yet, having conversations about retraction can help students understand that the scientific process is fluid. It is also an important part of the discussion on the peer review process, as some students might not know that peer reviewers do not duplicate a research experiment as part of their review.

Generally, retracted articles are marked in databases and journals, but they will still appear in a search. Retraction Watch keeps a running list of retractions across a variety of science, social science, and humanities disciplines.[31] Retraction Watch also indexes with the citation program Zotero, which could alert students during the search process to articles corrected or withdrawn after publication. The Chrome extension RetractOMatic can detect retractions in a Google Scholar or Web of Science search, using retracted information from PubMed.[32] Librarians and faculty can also use recent events on social media in the scientific community to engage students with research ethics and retractions. Retracting papers carries a stigma, but retractions or revisions acknowledge that even published articles can be wrong and honesty is ethically imperative. [33] These tools can also be part of discussions on reproducibility and replicability within a research area.

Collaborating in the Scholarly Conversation

While some digital tools can connect and clarify citations, there are also digital resources that allow researchers to discuss publications openly, in addition to social media. The benefit of these tools is that they bring together comments on a specific article. Some resources also allow students or researchers to collaborate in the scholarly conversation, which can work well in a classroom.

Open Comments

Websites that allow open comments on documents or promote transparency can give students insight into publications, helping them see how scholars evaluate and use other experts' research. Several tools can help students assess research by asking them to reflect on the larger processes of scholarly research and peer review. For example, open comments on some preprint servers allow students to read and consider the remarks of specialists in the field. *eLife*, a journal in the medical and life sciences, now publishes information that makes the publishing process more transparent. At the end of some articles, readers will find the feedback from peer reviewers and editors, as well as the authors' response to the peer reviewers. This can help students consider the ways in which experts critically analyze a research article, as well as how they communicate criticism, praise, and suggestions to each other. While some students may not be ready to evaluate research, reading the critiques of others can help contextualize the research in the broader scope of the field. Eventually, this may help students analyze and assess research on their own.

PubPeer

PubPeer is an online community forum that allows other scientists to comment on papers using identifiers such as a DOI.[34] Recently, PubPeer has been a place for discussions on image manipulation and data analysis. As an evaluation indicator, PubPeer is easily used as an extension. When a reader is on the website for an article with PubPeer comments, a bar will appear across the top to link the reader to the public conversation.

PubPeer enables readers to use open comments and social media to analyze a scientific article outside traditional peer review. This process could prompt class discussions about integrity and ethics during peer review and publishing. Students may feel that peer-reviewed research is verified, when in fact all research should be examined with a "critical lens."[35] In 2016, Elisabeth Bik, Arturo Casadevall, and Ferric Fang screened 20,621 papers, uncovering problematic images in at least 3.8 percent of them.[36] A limitation of PubPeer, or any open commenting community, is that students might not recognize the scientists assessing the articles, but this allows

conversations about authority in scholarship. There is also no way to ensure accuracy or validity of any comments made through these programs or websites.

Resources for Research in Any Discipline

As the usage of digital tools grows in scholarly research, it is clear that many of the digital tools described in this article can benefit other disciplines, as well as the sciences. A general rise in scholarship challenges a researcher in any new field searching for information. It is difficult to know which articles to read or how to organize resources, yet research is a starting point for conversation and collaboration in the classroom and research settings. The tools described in this section can support scholars in any discipline.

Discovering New Research

Kopernio

Kopernio is a user-friendly application developed by entrepreneurs and acquired by Elsevier that facilitates information discovery in the sciences, social sciences, and humanities with a one-click browser extension.[37] Users can seamlessly locate full-text open access documents. Like Google Scholar, Kopernio directs users to subscription-based content if the user is affiliated with an institution. Whereas Google Scholar is considered a passive full-text finder, Kopernio is an active finder of full text. Turned on all the time, Kopernio scans web pages and searches for the most user-friendly digital version of a full-text copy using a DOI.[38] Kopernio is easily added as a browser extension to both Chrome and Firefox. Kopernio Lockers is a feature that enables document storage, integrated sharing, and syncing with Dropbox. Today's students and early career researchers often fail to realize they pass through library web pages to authenticate and access subscriptions. Kopernio, while easy to use, further blurs the lines between subscription-based content and openly available material. Another issue is that Kopernio has access to a user's browsing data.

Evaluating and Interpreting Citations

PlumX

PlumX uses nontraditional measurements called altmetrics in combination with traditional citation metrics, such as impact factor and *h*-index, to help measure user attention to or engagement with research.[39] PlumX and other tools that incorporate altmetrics help demonstrate scholarly impact and connections with other researchers. PlumX provides five categories of analytics—citations, usage, captures, mentions, and social media—in a visual display. *Citations* include citation counts from Web of Science and Scopus, *usage* tracks downloads, and *captures* refers to bookmarks or other indications that someone plans to revisit the material. Blog posts, comments, and Wikipedia links constitute *mentions*; and *social media* includes Facebook likes and tweets.

PlumX, which primarily analyzes articles in the sciences, is integrated with Elsevier's Scopus and ScienceDirect databases to show interactions among researchers. Researchers can also find article metrics on some preprint servers, such as medRxiv, chemRxiv, and bioRxiv, which indicate how often an article has been downloaded or shared on social media. (See Figure 4). These article metrics allow users in any discipline to evaluate how scholars are using or sharing an article in a research field, giving users information beyond the citation itself. In the classroom, librarians and instructors can use this information to have conversations about how researchers interact with scholarship.

Collaborating in the Scholarly Conversation

Hypothesis

Hypothesis allows an opportunity to read open comments and enables users to work collaboratively online.[40] In this free Web-based tool, users digitally annotate material on the open Web, including articles, books, news, blogs, and legislation. Once the browser extension is enabled for Hypothesis, users can view annotations by others and add their own (see Figure 5). Social annotation is a way to seek input on research and other scholarship. It facilitates peer-to-peer learning and supports metaliteracy principles, wherein participants become collaborators and producers.[41]

Managing Citations

Organizing citations and managing citation styles can be a challenge to new researchers. Because expert

researchers often opt for citation programs such as EndNote, RefWorks, Zotero, and Mendeley, citation managers should be options in any research and writing experience. Students will need hands-on workshops to learn the benefits and applications of any citation manager their institution supports. Many students report that these tools help them focus on finding the right research for a task, rather than concentrating on formatting. Because students can easily organize articles and citations for each class or project, such tools may help them identify more resources to consider and provide an easy way to keep material as they find it, without committing to using it. In a similar way, Kopernio helps users save articles and citation files as they find them in databases.

Several of the other tools mentioned in this article also help scholars collaborate digitally during research, including citation managers. Collaborations could include sharing references or annotating research collectively. In a classroom, these tools can be used in a lab or group project to work together on related research topics, ask questions, and to share resources and ideas. Students can practice using the tools together and decide which would benefit them in other tasks.

Librarians' and Other Educators' Roles

The role of librarians in the digital realm continues to evolve, from embracing data management and digital scholarly communication responsibilities, to curating and managing information in a machine learning environment. [42] Librarians must assess the current research landscape and partner with users in their information journey.

Liaison librarians often know of emerging research within their subject specialties. For example, R, SPSS, and NVivo are Web applications that are widely used in a data-driven environment.[43] Python and APIs (application program interfaces) are other open source Web development tools. Some librarians working in data, STEM, or social sciences have experience with these specialized resources and can use them to share and curate digital material, leveraging their use to help reshape the profession.[44]

It is not enough to keep abreast of digital tools themselves. Librarians and educators must continue to gauge their users' needs. They must also immerse themselves in the culture of digital learning and scholarship to serve as mentors. This goes beyond traditional library subscriptions and resources. By working with campus partners, librarians can advocate support for nonlibrary resources and help close the gap in communication about using both library and nonlibrary materials.[45]

Not surprisingly, while researching these new digital tools, the authors found little literature in conventional sources such as databases, peer-reviewed articles, and monographs. Information and discussion appeared mainly on blogs and through social media and gray literature, such as unpublished reports. For instance, an article about Scholarcy appears on BMJ's website, digitalbmj.com, but not in the peer-reviewed publication *BMJ. Scholarly Kitchen*, a blog created by the Society for Scholarly Publishing, features a post about Kopernio and other access tools.[46]

Challenges and Limitations of Digital Resources

There are many advantages to discovering and interpreting research literature through artificial intelligence, where bots, computer programs that simulate human activity, filter and push information.[47] However, researchers may miss important things when the human element is removed from the discovery and exploration process. How do digital intermediaries handle a semantic shift in a word, or terms that do not produce optimal results? For example, the literature on self-driving cars has increased in a range of disciplines, including engineering, computer science, environmental science, behavioral psychology, and ethics. Do automated search systems manage controlled vocabulary and yield good results for such terms as *fully autonomous automobile driving*, *unmanned autonomous vehicles (UAVs)*, *automobiles—driver information systems*, or *remotely piloted vehicles*? Can a machine decipher an author's treatment of a topic accurately within the intended context and return just the right results to the searcher?

Change is a natural part of the open Web. Stability and permanence are significant challenges to digital tools. Researchers may find that a resource is not available the next time they need it. A survey of student and faculty researchers at North Carolina State University in Raleigh identified the rapid rate of changing technology as a

major challenge. Participants said they could not rely on a tool being available after a few years.[48] For example, a ResearchGate or Academia.edu article used as a source of reference may no longer be accessible on the site. Over time, the resources in this article may also shift or grow. Librarians and instructors will need to continuously practice using these tools to ensure they can help students and researchers.

To be a successful researcher, scholars must apply digital file management skills such as exporting, browsing, sharing, and downloading. This makes privacy and protection of intellectual property real concerns that carry over to the use of the digital tools described in this article. Students should be aware that some of these programs can collect their data and view their browsing history in real time. Research shows that many students worry about this prospect but accept it as "part of the deal" if they want the convenience of websites, apps, and digital resources.[49] Moreover, a free tool can turn into a paid service or require a subscription. While the tool may remain helpful, it can become unwieldy to manage additional accounts and incur monthly fees. Many users subscribe to tools with an institutional e-mail address. Once the user graduates or moves to a new institution to work or attend graduate school, valuable research may no longer be accessible. Conversations about such concerns should be part of any discussion about digital resources, and students should always be aware of any implications for a tool they use.

Assessing Tools and Future Research

The authors are interested in collaborations and empirical research with these tools in both classroom and laboratory research settings. The authors have also included some preliminary feedback from science students who explored these tools during a scientific writing course (see Table 2). These data were collected as part of a larger Institutional Review Board approved study on resource use and offer insight into how librarians and instructors might use these tools in the future.

Interested readers are encouraged to contact the authors. In the future, important questions to ask include how students value these tools and how often they use them. It would also be interesting to determine if students improve their ability to search or evaluate research by employing some of these digital resources. Because most students learn about the research process while working with a mentor, a study could assess if these resources can help students become more cognizant of the research process without that traditional research experience. Researchers may develop skills, perhaps unintentionally, in response to their quest for information.

Conclusion

Digital resources offer an opportunity to teach students about challenges and trends in scholarly communication. Communicating effectively and efficiently about research in the digital environment is a top twenty-first century digital literacy skill and is essential for advancing information literacy.[50] Librarians and instructors can begin these conversations with students, ultimately helping them understand the process, challenges, and potential of research in an authentic way. By engaging in digital communication as novice learners and participants, students learn ways to navigate a vast and changing landscape of scholarly research. The valuable skills of discovery, collaboration, and analysis build a foundation of information literacy that can transfer to future research experiences.

Notes

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