3-13-2023

It's Harder Than it Looks: How Students Identify Original Research Articles in an Undergraduate Biology Course

Alyssa Russo
University of New Mexico, arusso@unm.edu

Amy Jankowski
University of New Mexico, ajankowski@unm.edu

Recommended Citation

Russo, Alyssa and Amy Jankowski. "It's harder than it looks: How students identify original research articles in an undergraduate biology course." Public Services Quarterly (2023). doi: 10.1080/15228959.2022.2116377

It's harder than it looks: How students identify original research articles in an undergraduate biology course

Alyssa Russo and Amy Jankowski

Biology students must develop a foundational understanding about the role information plays in the scientific research process. Key to this is understanding that original research articles are the primary method of communicating findings from original scientific research. We analyzed data from an information literacy tutorial and worksheet integrated in a core undergraduate biology course to investigate how students identify original research articles. Our results suggest that students conceptually comprehend original research, but they need practice at identifying original research articles in real time and benefit from librarian feedback when they are actively searching for and selecting articles.

Keywords: information literacy, undergraduate students, biology, primary literature

Introduction

The work that biology students are tasked with doing in their labs, testing hypotheses by performing experiments and completing lab reports, serves as a model for how scientific knowledge is generated. Biology lessons often require students to go beyond their textbooks to analyze the literature in support of their assignments. Yet it is well-documented that developing science literacy, which includes understanding scientific methods and interpreting data, is challenging for novices (Hoskins et al., 2007; Howard et al., 2021; Hubbard & Dunbar, 2017; Nelms & Segura-Totten, 2019; Stengel et al., 2021).

Information literacy (IL) complements science literacy in a couple of key ways. First, students need to learn how to access the scientific literature in order to analyze it. On a more conceptual level, IL has a part to play in illustrating the evolution of ideas in a specific area

of study through scholarly conversations. The Association of College and Research Libraries Science and Technology Section Information Literacy Framework Task Force (2021) recognizes that the peer reviewed research article remains the dominant format in the sciences, and learners should "start to develop a deeper understanding of creation processes relevant to their work and discipline." IL supports a holistic conceptualization of science literacy by nesting the scholarly publication process within the larger scientific research process.

The present qualitative study investigates how undergraduate biology students recognize original research articles following IL instruction. We analyzed student responses to a selection of questions in order to understand students' abilities to recognize original research conceptually, through examples, and in their own literature searches. We also examined common lines of reasoning that students used when explaining their thought processes as they determined that an article was original research. In addition, because of a required transition from hybrid to fully online instruction, we had the opportunity to evaluate implications of these instruction modalities. Our findings will help to inform future IL instruction around scholarly formats in the sciences.

Literature review

One challenge of teaching students to analyze scientific information is the scarcity of class time available to cover dense scientific knowledge (Fuselier & Nelson, 2011; Hoskins et al., 2007). Instructional collaborations between librarians and biology faculty to scaffold IL into larger biology course curricula is a popular approach to mitigate the time crunch issue while increasing student engagement in IL instruction. Several collaborative case studies focus on embedding IL into biology curriculum, often across a course unit or an entire semester (Barkley, 2018; Borchardt et al., 2019; Ferrer-Vinent & Carello, 2008; Fuselier & Nelson,

2011; Gamtso & Halpin, 2018; Petzold et al., 2010; Porter et al., 2010; Tsunekage et al., 2020).

In addition to developing effective instruction models, several case studies about IL assessment projects shed light on core IL curriculum taught to undergraduate biology students. Librarians have tracked student perceptions of their IL skills using pretest and posttest self-assessments. Building on Ferguson et al.'s (2006) earlier work establishing baseline IL skills, Fuselier and Nelson (2011) found improvements in students' confidence identifying primary and secondary science literature, evaluating source credibility, and formatting citations after receiving IL instruction. Lantz and Dempsey (2019) conducted focus groups with biology students who previously completed IL instruction to explore their understanding of subject-specific database use, source reputation, source relevance, and citing sources. Shifting from students' self-perceptions to students' performance, Rose-Wiles et al. (2017) used a rubric to assess source quality, relevance, integration, and citation formatting within lab reports completed after students received IL instruction. These studies rarely define or describe the elements of IL they assessed, and there is little focus on granularly exploring how students develop discrete IL skills. The curricular theme running through nearly all studies is a broad emphasis on finding and citing scientific journal articles.

It is also helpful to understand how IL is related to science literacy. Science literacy encompasses understanding science as a process of inquiry, design, and communication (Klucevsek, 2017). To improve science literacy instruction, science education researchers have studied students' practice of reading scientific literature. Common challenges undergraduate students face when reading primary literature include "issues with jargon, lack of knowledge, and complex writing structure," which increase cognitive load for students (Howard et al., 2021). Hubbard & Dunbar (2017) specifically found that the methods and

results sections of journal articles were the most difficult sections for undergraduates to understand. Several approaches have been developed to promote learner engagement while managing cognitive load and the anxiety associated with reading primary literature. Hoskins et al. (2007) developed a widely cited method, CREATE (consider, read, elucidate hypotheses, analyze and interpret the data, and think of the next experiment), that helps students understand a single line of research across a sequence of articles produced in the scholarly conversation. Nelms & Segura-Totten (2019) studied strategies for lowering cognitive load and identified two key techniques for success, summarizing and note-taking. Similarly, Howard et al. (2021) noted the importance of "productive failure" by requiring students to summarize article content before instructors supply students with the big picture of the article. In light of COVID-19, Stengel et al. (2021) pivoted to a virtual journal club, which offered students a structured learning environment with frequent feedback as opposed to a self-directed experience when reading primary literature.

When lacking technical science backgrounds, instruction librarians may view science literacy pedagogy as falling outside of their domain. Yet, librarians possess complementary expertise involving threshold concepts that disciplinary faculty tend to overlook in their teaching. In his call to action, Carroll (2020) explains how librarians may find "easier access to the 'novice mind' than might a disciplinary expert, and as a result can provide relevant strategies for early-career graduate students on how to best engage with the dense morass of technical information found in primary literature" (p. 301). One relevant strategy in approaching science literacy through information literacy that is well-suited to librarians is source evaluation informed by the threshold concept of information formats, or simply "format."

Closely related to the Association of College and Research Libraries Frame, Information Creation as a Process (American Library Association, 2015), format works as a

contextualizing framework for information. Hofer, Lin Hanick, and Townsend (2019) proposed format as one of five information literacy threshold concepts. They define format:

> Each instance of a format shares a common intellectual and physical structure with others like it, and is intentionally produced to support or effect action. Intellectual structure refers to the textual and visual content of a format. Physical structure refers to the organization, design, and medium of a format. These categories are not strict and may overlap. (p. 82)

Original research articles, review articles, and news briefs found in a scholarly journal are all examples of different formats. As opposed to focusing on the specific ideas or content communicated through information, a format is defined by the typified physical form of the information as well as how and why information is created. By centering attention on the purpose of information and the processes that go into producing information, format knowledge is key to unpacking a common goal in IL instruction: finding and using appropriate and credible sources. Librarians and disciplinary experts understand how to recognize formats in their disciplines, but students often lack the context to discern format, including what a format's typical process of creation and communicative purpose in the world imply about the content, which is relevant when searching for, evaluating, and selecting sources.

Some instruction librarians have approached the intersection of science literacy and format. Shannon and Winterman's (2012) instruction centered students' ability to read primary scientific literature by teaching pattern recognition of the common text structure within research articles. Patterns in text structures, such as IMRD (Introduction, Method, Results, Discussion), are useful clues in identifying information formats. Likewise, Klucevsek and Brungard (2016) emphasized primary article structure in their study about students' ability to

distinguish primary and secondary articles.

Yet, teaching and learning about format remains tricky. Format may have been an easier concept in the pre-internet age when a limited range of formats passed through traditional publishing processes. However, the nuances of format may not be easily understood in an ever evolving, ever growing quagmire of digital information spurred on by the advent of the internet (Brante & Strømsø, 2018; Lindquester et al., 2005; Park et al., 2011). For example, Greer and McCann (2018) asked students to identify digital sources and found that students have difficulty correctly identifying books and journal articles. Gehring and Eastman (2008) zoomed into the formats within scientific literature and found that students lacked clarity on differentiating between review articles, opinion essays, and primary journal articles. While some librarians are studying format, there is a need for more research in this area.

Interestingly, other fields of study have researched concepts related to format. Brante and Strømsø (2018) reviewed similarities across social psychology, information and communication research, and discourse research based on genre theory in their article discussing the ways in which contextual information about documents is used to evaluate information. With particular interest in science, Lammers et al. (2019) "investigat[ed] the genre characteristics that undergraduate students use in their written science texts." Bromme et al. (2015) studied how undergraduates used genre knowledge to interpret and judge controversial issues in different types of science articles. Format, and these related concepts, offer readers a fuller, richer mental model to comprehend information, including primary scientific literature.

Materials and methods

Institutional background

Our study's research population includes undergraduate Biology students enrolled at the University of New Mexico, a large, Hispanic-Serving Institution and a Doctoral University with Highest Research Activity (R1), which serves approximately 20,000 undergraduate, graduate, and professional students through more than 215 degree and certificate programs. The Biology undergraduate program is typically the second or third largest degree program in the College of Arts and Sciences each year, with nearly 600 enrolled undergraduate Biology majors and 400 undergraduate Pre-Biology majors in both 2020 and 2021 (University of New Mexico Office of Institutional Analytics 2022). The curriculum for Biology majors includes four core laboratory/lecture courses. Library IL instruction has been integrated into two of the four core courses for many years. The most critical library instruction occurs in the second core course, BIOL 2410C: Principles of Biology: Genetics Lecture and Laboratory. Most students complete this course during their second year at UNM.

Participants and setting

The BIOL 2410C library instruction is aimed at giving students an introduction to disciplinary research tools, database search techniques, formats for science communication, and the connection between information formats and scientific research. Major goals of the instruction surrounding information formats are for students to understand that scholarly journals publish a variety of article types. We want students to learn how to distinguish original research articles (primary research) from other formats commonly included in scholarly journals, such as review articles (secondary sources that summarize and interpret primary literature). Students apply what they learn in an end of term project, where they work in teams to create a research poster that reviews primary literature on a genetics topic of the

team's choice. According to the course instructors, distinguishing between primary and secondary sources has been a recurring problem for students, and we designed our library instruction with the intent to solve this.

Beginning in Fall 2019, we transitioned library instruction from an exclusively in-person workshop scheduled outside of class time to a flipped hybrid model including an asynchronous online tutorial and in-person worksheet with librarian support. This approach is intended to help students apply concepts they learned from the tutorial in the worksheet, where they develop a literature search and select an original research article that could be used for the course group poster project. In response to the COVID-19 pandemic and a university-wide push for virtual courses, in Fall 2020, we transitioned the workshop to a fully asynchronous online tutorial and worksheet model. In both the hybrid and fully online iterations, both portions—tutorial and worksheet—are required graded course assignments. In both modalities (hybrid and fully asynchronous online), students were instructed to complete the tutorial and select a topic for their group project prior to completing the worksheet.

Our present study uses data from both the tutorial and worksheet from the Spring 2020 and Spring 2021 semesters. We selected these semesters because enrollment and participation numbers were relatively comparable, and we were curious to explore any significant differences between hybrid and fully online instruction models. All materials and procedures were approved by the UNM Office of the Institutional Review Board.

Materials

We deployed both the tutorial and worksheet through the online survey platform Qualtrics; sample versions are hyperlinked here. Our study focuses on a selection of questions from each, which are described as follows. In the tutorial, students are presented with the same question twice: once in a pretest, to test prior knowledge, and once in a posttest, to test

knowledge gained. The question is multiple choice, asking "What is an original research article?" with four possible answers. This same question is also used at the start of the worksheet. In the worksheet, students must additionally answer the multiple choice question, "Which one of the following articles is a genetics original research article?" and they are given four example articles of differing formats to choose from. Also in the worksheet, students are asked to search for and select an original research article, and share the article title, author, and journal. Students are then asked to answer the following question in their own words in reference to their selected article: "How did you determine it was an original research article?" We linked student responses from both the tutorial and worksheet prior to de-identification and analysis to enable us to determine the order in which students completed both portions.

Design and analysis

First, we determined the number of students in our sample that correctly answered multiple choice questions from both the tutorial and worksheet. We then checked articles using citation information (article title, author, and journal fields) to determine if students chose original research articles versus other types of articles. We grouped student article selections into five categories: original research article in genetics (required for project), original research article in another subject, articles with some elements of original research but not in the official format (i.e. reports, letters, etc.), articles that are clearly not original research (reviews, websites, etc.), and articles that we couldn't determine based on faulty citation information.

Second, we developed codes inductively based on student responses to the question "How did you determine it was an original research article?" (Schreier, 2012). Codes describe the content of student responses. We developed an initial set of emergent codes after a single

round of coding our Spring 2020 dataset. We applied, added to, deleted, merged, and edited these codes through multiple rounds of coding review for both the Spring 2020 and Spring 2021 datasets until we felt confident that our codebook adequately categorized the full range of student reasoning present. Our final list of 48 codes with corresponding definitions and examples is available in the Appendix.

After we agreed that our codebook was complete, we pursued a final round of coding to serve as our dataset for analysis. We first coded each dataset independently and then negotiated final consensus codes through collaborative discussion. We elected not to measure interrater reliability, as our coding process required subjective interpretation of students' responses, which were often vague or could be interpreted in multiple ways, thus the nuanced perspectives that each coder brought to the process were perceived as a strength in determining final consensus. Multiple codes were usually applied to a single student response to capture the unique, multifaceted reasoning typically present. For example,

> *"I saw that it was labeled as "article" and that it had an introduction, methods, results, and discussion section. I also saw that it was published by a peer reviewed journal."*
>
> Codes assigned: label, IMRD, introduction, methods, results, discussion, scholarly, peer review

After we completed coding, we reviewed code frequency and identified codes that correlated to correct or incorrect identification of an original research article. Next, we employed basic concept mapping to explore code relationships and group codes into broader themes for analysis. To further explore trends in the data and confirm code grouping, we pulled all student responses corresponding to each code. This allowed for a deep, nuanced content review as we investigated broader themes.

Limitations

Our study was limited by its data collection instruments, the tutorial and worksheet. The multiple choice and short answer format limited our ability to develop a deeper understanding of student thinking and experiences. Often, student reasoning was vague, confusing, or could be interpreted in multiple ways. For example, mention of the presence of "methods" in an article could refer to an actual "Methods" section or the fact that the article describes a study where some sort of task/action/process was performed that generated data. We collected our data in a way that did not allow for follow up questions or discussion with students to draw out exactly what they were trying to communicate, as we could have in an interview or focus group setting. Because of this, we coded responses at face value and often had to generalize what a student might be trying to communicate. We used an *unclear* code to categorize student reasoning that was unintelligible. In addition, we were not able to understand students' larger experiences with searching the literature (e.g., did they struggle with their search terms? were they confused about the search interface?), which could impact their confidence and success in identifying an original research article.

The change to our library instruction structure brought about by the COVID-19 pandemic, where our in-person synchronous worksheet portion transitioned to an asynchronous online worksheet, presented another limitation in understanding data across semesters. This change likely impacted student experiences and learning outcomes. In 2020, students completed the worksheet along with librarian consultations and support in identifying original research articles. In 2021, students completed the worksheet without librarian support. Though this change brought about an interesting point of comparison between hybrid and fully online learning, we also noticed that it came with significant changes to the order in which students approached the instruction. In 2020, though we designed the instruction as a flipped model where students would first complete the online tutorial and then complete the in-person

worksheet, only 34% of participating students completed the materials in the intended order; in 2021 where materials were fully online, 82% completed the materials in the intended order. This change, in addition to the impacts of stress and complications brought about by the pandemic, makes it difficult to directly compare outcomes across semesters since students completed materials after different levels of instruction.

Results

The study analyzes data from 216 tutorial responses and 242 worksheet responses. In Spring 2020, 101 students completed the tutorial, with 82 consenting to the research study; 133 completed the worksheet, with 114 consenting to the research study. In Spring 2021, 154 students completed the tutorial, with 134 consenting; 144 completed the worksheet, with 128 consenting.

Results from the first three tutorial and worksheet questions we analyzed are presented in Table 1. The multiple choice question, "What is an original research article?" was posed to students at three different points across the worksheet and tutorial. Overall, responses were highly accurate. Students were usually able to select the correct definition of an original research article from a list of format descriptions. In 2020, 77 of 82 students (94%) answered correctly in the tutorial pretest, 75 of 82 (91%) answered correctly in the tutorial posttest, and 111 of 114 (97%) answered correctly in the worksheet. In 2021, 125 of 134 students (93%) answered correctly in the tutorial pretest, 132 of 134 (99%) answered correctly in the tutorial posttest, and 125 of 128 (98%) answered correctly in the worksheet. The high overall success suggests that students may have had prior knowledge of original research articles, and their knowledge stayed relatively consistent across our instruction.

Table 1: Number and Percentage of Students that Correctly Answered Select Tutorial and Worksheet Questions

Question / Prompt	**Library Instruction Component**	**2020 Modality: Hybrid, Asynchronous Online Tutorial, In-Person Worksheet**	**2021 Modality: Asynchronous Online Tutorial and Worksheet**
What is an original research article?	**Tutorial, pretest**	77 of 82 (94%)	125 of 134 (93%)
	Tutorial, posttest	75 of 82 (91%)	132 of 134 (99%)
	Worksheet	111 of 114 (97%)	125 of 128 (98%)
Which one of the following articles is a genetics original research article?	**Tutorial, posttest**	Original research article, genetics subject: 61 of 114 (54%) Original research article, any subject: 89 of 114 (78%)	Original research article, genetics subject: 93 of 128 (73%) Original research article, any subject: 101 of 128 (79%)
Search for and select an original research article.	**Worksheet**	102 of 114 (89%)	79 of 128 (62%)

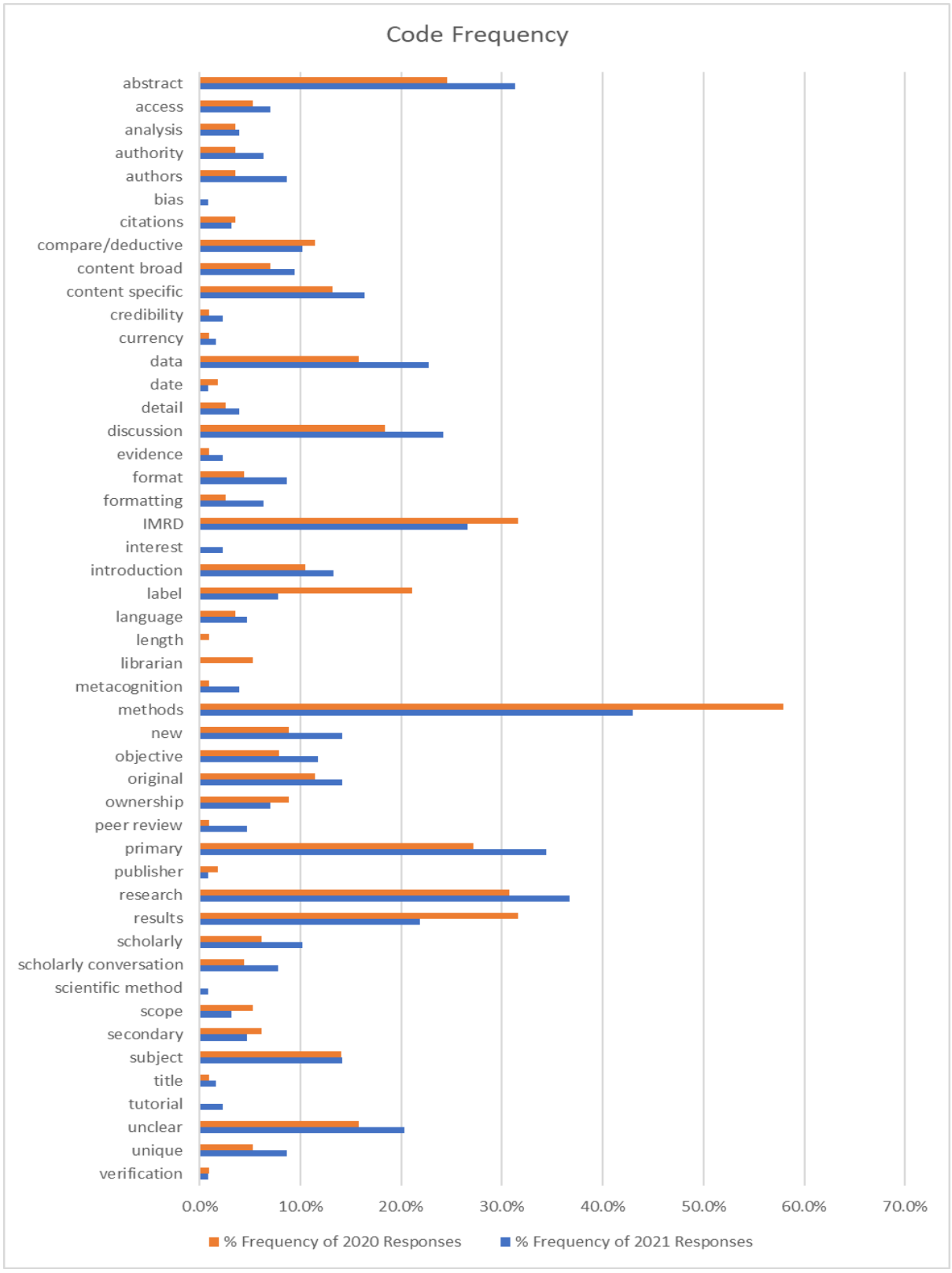
The success rate dropped when students were asked to select from four example articles in response to the question, "Which one of the following articles is a genetics original research article?" The answer options included a review article, letter, genetics original research article based, and social science original research article. Because students were required to use original research articles that engaged in genetics research for their course assignment, this question was intended to make students think critically about article format as well as research subject. In the 2020 worksheet, 61 of 114 students (54%) selected the correct genetics original research article; an additional 28 selected the social science original

research article, meaning that 89 (78%) of students selected one of the two original research articles. In 2021, 93 of 128 students (73%) selected the correct genetics original research article; an additional 8 selected the social science original research article, thus 101 (79%) selected one of the two original research article options. This difference suggests that while students are highly likely to have an idea of what an original research article is, some experience difficulty identifying one in real time. These results also suggest that some students experience difficulty differentiating information formats commonly found in scholarly journals.

When students were asked to search for and select an original research article, plus share the article title, author, and journal, they had mixed success. In 2020, 102 students (89%) correctly selected an original research article. In 2021, 79 students (62%) correctly selected an original research article. One possible explanation for this difference is that it could be correlated to the different modalities of instruction in 2020 versus 2021. In 2020, when students were significantly more likely to select the correct original research article, they did so in the context of an in-person worksheet session with immediate librarian support. In 2021, they completed the worksheet asynchronously online without a direct line of help, which may have been a more important factor in success than the fact that they completed the tutorial first at much higher rates than in 2020.

The remainder of the results concerns the qualitative coding of responses to the fourth question that we analyzed, “How did you determine it was an original research article?” Figure 1 indicates the percent frequency that each code was applied in both 2020 and 2021. This shows how common each method of reasoning was among student responses each year.

Figure 1: Code Frequency Across Student Responses in 2020 and 2021



Four of the top five codes were consistent across 2020 and 2021, though the precise order varied: *methods, IMRD, research, and primary; results* ranked in the top five in 2020, and *abstract* was in the top five in 2021. These most frequently applied codes remained consistent among the subgroup of students who correctly identified an original research article. A slightly different set of top five codes emerged among the subgroup of responses when students incorrectly identified an original research article. In addition to *methods* and *research*, students who incorrectly identified original research articles were most likely to use reasoning corresponding to the *compare/deductive*, *label*, and *results* codes in 2020, and the *abstract*, *primary*, and *unclear* codes in 2021. These results indicate that students most frequently refer to elements of article content and structure in their reasoning. The findings also suggest that students often apply similar reasoning both correctly and incorrectly.

Through qualitative analysis, we grouped codes into six major themes: (1) students practiced reflection and metacognition, (2) students investigated the article's subject area, (3) students valued markers of authority, (4) students used article contents as evidence of original research, (5) students used article characteristics as predictors of original research, and (6) students negotiate originality. The specific codes categorized under each theme are indicated in Table 2. The discussion of themes that follows further explores the meanings underlying these qualitative findings.

Table 2: Themes, Subthemes, and Corresponding Codes

Theme	**Subtheme**	**Corresponding codes**
Students practiced reflection and metacognition		access, compare/deductive, librarian, metacognition, tutorial, verification

Students investigated the article's subject area		interest, subject
Students valued markers of authority		authors, authority, bias, credibility, publishers
Students used article content as evidence of original research	Core sections of original research articles	abstract, discussion, format, formatting, IMRD, introduction, methods, objective, results
	General uses of content	analysis, citations, content broad, content specific, data, detail, evidence, language, length, scope, scientific method, title
Students use article characteristics as predictors of original research	General characteristics	currency, date, label
	Scholarly characteristics	peer review, scholarly, scholarly conversation
Students negotiate originality		new, original, ownership, primary, research, secondary, unique

Discussion of themes

In this section, we discuss each theme and use quotations from students' open-ended responses in the instruction worksheet to illustrate lines of thinking. To preserve students' authentic voices, all example quotations are presented exactly as written by students without corrections to minor spelling and grammatical errors. The themes are interconnected and sometimes overlap, as elements of format, authority, and student evaluative behavior are intrinsically linked. Each theme presents a unique angle and a particular interpretation of students' responses, however these responses were complex, and our qualitative evaluation often gave rise to multiple meanings that intersected with multiple themes. As a result, sometimes a code will have a secondary relationship with a code in a different theme, and

these relationships are evident in our discussion.

Students practiced reflection and metacognition

Students were reflective of the actions they took in determining whether an article was original. Responses described technical steps taken, self-reflective monitoring processes, and evaluative processes used to arrive at a conclusion. In some cases, students reported their search strategy by referencing the library, naming a database, describing the search refining options they selected, or basing their decisions on metadata provided by the database.

> *"I was able to determine that my article of choice was an original research article by refining my search many times. I refined my search by literature types, by marking the first author option, and by not clicking the highly cited in field option. This method helped but I am not completely sure this was sufficient."*

> *"I refined my search to articles since there was not a specific button for original research article. I also went to Web of Science database for accuracy."*

In some responses, students referenced working with a librarian or the tutorial in their approach to making a decision.

> *"I also had Amy Jankowski, the bio librarian, help me confirm it was an original research article"*

> *"I read the abstract using techniques I received via the tutorial"*

We also noticed a pattern in the way students reasoned by process of elimination. The code *compare/deductive* captured instances when students ruled out something about their article in order to qualify it as original. This code focused on the type of reasoning students applied as a part of their approach rather than the content or context that gave rise to the approach.

"I reviewed the...authors to make sure it was written by a scientist and not a journalist."

"I determined this was an original research article by avoiding the word review"

While less frequent, some responses included comments about students' confidence level in their decision making or a general summary of their process.

"...I might be incorrect in determining if this is an original research article though."

"If this isn't original then I have a back up that I believe is very original."

A couple of students ambiguously described verifying information in the article as part of their process. While also linked to authority, we particularly valued these responses as indicators of students taking an active extra step in their evaluative process through lateral reading (Wineburg, 2017).

"The publisher allowed me to determine if the article was valid because I was able to search the publisher and the authors who wrote it."

With the exception of the *compare/deductive* code, the codes in this theme infrequently appeared in the data. While student success at identifying original articles was mixed within this theme, students' ability to self-monitor their learning is an important tool in teaching and learning (Bransford, Brown, & Cocking, 1999). We value seeing evidence of metacognition, which encourages students to improve their own learning processes in the future.

Students investigated the article's subject area

For this study, we were most interested in how students decided their selected article was an original research article. Library instruction for BIOL 2410C, however, also supported students in finding an article about genetics where the researchers engaged with genetic data

in their analysis. As a result, several students included reasoning that the article's subject focused on genetics. Sometimes students made broad comments about whether the article fit their general interests or matched their information need.

> *"when I first read the abstract I immediately knew the article was addressing my desired topic.*"

> *"... because UNM doesn't have any of the articles I was interested in..."*

Other times, students made more specific connections about how their article focused on genetics, often by using the methods section.

> *"...I looked at the research methods and results to ensure that the research methods involved DNA/genetics..."*

> *"Then I reviewed the article and found that it did indeed use genetics 'viral RNA was extracted...this was followed by deep-sequencing analyses...'"*

In a few cases, students discussed the specific topic of their article and drew a relationship between the scope of the topic and the article format.

> *"The subject was so niche that it had to have been a primary study. This was a study on wolf fecal matter."*

> *"It is approaching a specific topic."*

It is encouraging that most students who tied the article's subject into their reasoning drew on format knowledge by articulating their process of checking either the abstract, methods, or results section to pinpoint where they expected to verify that the article included genetic data in the analysis.

Students valued markers of authority

Several students included observations about the authors, publisher, and other indicators of traditional authority within their responses. Students associated the presence of multiple authors with authority.

> *"It had multiple authors addressing their newly conducted research."*
>
> *"This article is an original research article as it was written by a group of scientists..."*

They were also influenced by high citations, whether a scholarly or medical institution was associated with the article, and whether the authors were credentialed or qualified professionals.

> *"... and based off of how many times the research had been cited (over 300)."*
>
> *"The article came out of the Texas tech university of heath winces..."*
>
> *"... the authorship indicated professionals well versed within their field..."*

While infrequent, some students indicated that they trusted the article by checking for bias or credibility as part of their reasoning. Few also mentioned that they went a step further and reviewed the creators in some way to establish a sense of trust.

> *"I determined that it was an original research article because it is from a credible website."*
>
> *"It was peer reviewed and also searched the name if the author to learn more about."*

The concept of authority is a pillar of IL, and librarians often teach about credibility, markers of authority, and bias. In BIOL 2410C, the concept of authority is more subtly woven into instruction. With a focus on scholarly information formats that pass through peer review and

are accessed through recommended library databases, a certain amount of credibility can typically be assumed, as compared to information in an open web search. The original research article format often assumes credibility. The focus is less about establishing biology researchers' credibility and more about understanding scholarly communication formats as the products of researchers' actions. Therefore, it was interesting to see authority emerge as a theme. Beyond the inherent connection between information products and creators, it may indicate that these students received previous library instruction and they tapped into prior knowledge from introductory lessons, adding those understandings to this new layer of disciplinary instruction. While this implication is speculative, it is encouraging to consider how students may scaffold IL learning across their academic careers.

Students used article content as evidence

Students described skimming their article and using the contents of the article text to determine whether it was original research. Because student responses were typically brief and we were unable to ask follow-up questions, content is defined broadly in this study. This theme is divided into two subthemes that address two general strains of thinking. First, within the *Core sections of original research articles* subtheme, content refers to typified formatting that students expected to see, like section headings. Second, within the *General uses of content* subtheme, content refers to specific ideas communicated within the article text, or specific types of information usually found in original research articles, like numerical data or citations. Students frequently reported the presence of content without providing further explanation, although some students did provide an explanation of how the content acted as evidence of original research.

Core sections of original research articles

From their IL instruction, students learned about the typical structure found in original research articles. Students frequently put this teaching into practice by scanning through their selected article, sometimes only needing the abstract, to look for the four core sections: introduction, methods, results, discussion (IMRD).

> *"This is an original because it has the introduction, methods, results and discussion"*
>
> *"First I made sure that all the necessary sections were present."*
>
> *"Its a study with results about what they did, including their research, hypothesis, steps taken in experiment as well as results and what to continue doing after finding results"*

Interestingly, both the students who correctly and incorrectly identified an original research article discussed scanning for the core IMRD sections. This is noteworthy because it indicates that students may rely on surface level indicators of format without real engagement with the content, or a fundamental disconnect between primary and secondary research.

Beyond naming the presence of sections, some students provided big picture explanations about what a section was communicating. For example, when students pointed out the methods section, they may have included specific details about the methods used or broadly indicated an experiment was performed.

> *"Under the method section, it mentioned 2 methods: exome and panel sequencing that were used to analyze the genetic materials."*
>
> *"The methods section also outlines how they performed their experiment, step by step."*

> *"It showed the specific results they acquired after completing their experiments. Showing how the Cartilage tissue grew"*

In some cases, students vaguely mentioned the article's formatting but never specified the core sections. In these cases, it was clear that students were characterizing the distinctive pattern to which the content in original research articles conforms.

> *"It is laid out and structured as an original research article."*

> *"... also the way it is organized make me determine it is an original research article."*

> *"Formatted like a research article."*

In addition to the four core sections in original research articles, students commonly reported reading the abstract to quickly find clues about their article without having to read the full text.

> *"I read the abstract, and it discusses the findings of their experiment, and the results section has their original data and graphs."*

Overall, a number of the codes grouped under this subtheme were among the top applied in student reasoning. Students often referred to general formatting as well as specific sections when explaining why it was an original research article, but the high frequency by which these codes were applied when students both correctly and incorrectly identified an original research article suggests that some students may have difficulty engaging critically with the content of an article to understand nuanced meaning.

General uses of content

Aside from the core sections typically found in original research articles, there were other, more general observations about content used to recognize original research. Students

described the article text in terms of length, detail, or scope. Students noted how exhaustive and richly detailed the article was, especially in terms of the methods. Some students observed the narrow specificity of the article.

"it gives explicit detail of the new techniques used in gene editing for cancer."

"It was an original article because it is very specific..."

"Not only that but all aspects of the article have great detail."

Students also pointed out the presence of data in their article, and they frequently indicated that it had been processed by the authors.

"original data was collected and analyzed."

"Saw analysis of collected data and graphs with conclusions."

"They conducted their own experiments and most data is analyzed by themselves..."

Several students additionally called out the presence of citations in their article.

"I made sure it had... [a] references section."

"There was also...multiple references."

Some students reported that language, a particular phrase or keyword, was important to their reasoning. Often, students pointed to language that indicated if a source represented primary or secondary research.

"I determined this was an original research article by avoiding the word review..."

"in the methods and results they specify how they conducted the research by saying "we" making it clear it is their research."

> *"It contained the word 'demonstrated' and '... identified'. These terms convinced me that some type of experiment was being conducted."*

In a similar approach, many students were persuaded by longer quotes and ideas expressed through the content. As mentioned earlier, some students included a quote without explaining its significance, and others vaguely referenced content.

> *"It said 'The human protein apolipoprotein A-I binding protein (AIBP) inhibits HIV replication by targeting lipid rafts and reducing virus-cell fusion, according to a new study.'"*

> *"The content of the article suggests the authors did the research themselves."*

When students did provide more explanation of a quotation, it was usually to indicate the article's subject area within genetics.

> *"How I determine that it was an original research article because when I was reading the abstract one of the sentences stated 'here, we developed a lipid nanoparticle-encapsulated mRNA (mRNA-LNP) encoding...' When the abstract stated this I know it is an original research article because they conducted their own research, observation and data."*

While infrequent, students also reported that they specifically looked to the title for clues.

> *"... the title is very specific with what gene the research study is talking about."*

We found mixed success among students who used content to identify original research articles, which may indicate how hard it can be to read and comprehend the text of an article, or even the abstract.

Students use article characteristics as predictors of original research

Article characteristics include typified features, markers, or qualities of the article that are often external to what the author created. Article characteristics are somewhat removed from the literal message being communicated in the text, and students are not usually directly engaging or reading the text. Instead, these characteristics offer contextual clues about the information format. There is some overlap with the *Students used article content as evidence* theme, as both intersect with the concept of information formats and the typified elements of original research articles. The article contents theme focuses on the things the author created and put into the text of the article (e.g. ideas, titles, language, data, etc.). We distinguish article characteristics by separating them from the text of an article and framing them in subtexts of latent meaning (Wineburg, 1991, p. 498). Characteristics act as evidence of the article's broader context. We divide this theme into two subthemes, *General characteristics* and *Scholarly characteristics*.

General characteristics

Certain characteristics outside of the article text, such as a label or publication date can hint at information's creation process. In the case of labels, students described some that are assigned by the journal and usually found at the top of published articles; other times the labels were found in database records.

> *"it says 'original article' near the article title"*
>
> *"I mainly looked at the very top of the page to see if it said research article"*
>
> *"I checked the label in web of science to see whether it was an article or something else."*

Students also pointed out the publication date, and some further expressed that the information was current.

> *"... and it was published in 2019."*
>
> *"I saw that it was recently published."*

We admit that labels are confusing because they are not standardized across all journals. Labels on original research articles may say "article," "original article," "research article," and more. Interpreting labels often requires prior knowledge and may involve engaging with content to double check initial expectations gleaned from the label, yet we consider labels to be a reliable indicator of format.

Scholarly characteristics

Several students noticed indicators that the article was produced by and for a niche community of scholars. Students indicated that the article had gone through a scholarly publication process, often specifically calling out peer review, though the actual information they used to identify this quality control process was unclear.

> *"I determined the article as an original article because it is published in a journal on research in Alzheimer's and Dementia..."*
>
> *"Over viewing the article and checking that it was presenting original research to be reviewed by experts and later published in a journal."*
>
> *"I also saw that it was published by a peer reviewed journal."*

Another pattern emerged where students connected their article to the larger scholarly conversation. While challenging to determine how sophisticated this understanding was,

students pointed to evidence of other articles or datasets that came before their selected article, and some loosely described how their article was contributing to gaps in knowledge.

> *"The authors also talked about how they method was and different from past research."*
>
> *"the article talks about...how the methods and results advance the field of study."*
>
> *"... it was in fact an original article but piggybacked on a huge data set and previous works."*
>
> *"The purpose of this article is a platform for complex ideas and conversations."*

The characteristics used in this subtheme demonstrate students' broad understanding that their articles are scholarly sources following conventions expected in academia, such as contributing to a scholarly conversation using previous works, or having passed through quality control processes, like peer review.

Experts use article characteristics, "to predict, interpret, and evaluate documents' content and relevance according to a reading task" (Brante and Stromso's, 2017, p. 777). In this study, however, we worked with novices practicing observing patterns that carry subtext. Students usually did not expand in their reasoning about how article characteristics hint at the underlying process or community in which the article was produced. Therefore, we speculate that students are engaging at a surface level, checking for the presence of these characteristics.

Students negotiate originality

The fundamental goal of IL instruction for BIOL 2410C is to teach students how to recognize original research articles. The themes thus far have addressed several approaches hovering

around this core learning goal. Observations about the IMRD structure of the article or whether the article passed peer review are true of original research articles, but these elements alone do not constitute original research. The critical reasoning we wanted to see was that students selected articles where the authors wrote about a new study that they conducted themselves. Many students were able to articulate this in their reasoning.

> *"Because the article is a presentation of research done by the authors."*
>
> *"I found sentences that directly mentioned new research the authors had conducted themselves."*
>
> *"The authors primary goal is to present information about a new study, that included their research question, what they did, and the study's result"*

We additionally saw a variety of incomplete and sometimes surprising reasoning related to the concept of originality. Students often described articles as new and/or original, but these descriptions were challenging to interpret. Sometimes it seemed plausible that these terms were synonyms for primary research. Students explained themselves matter-of-factly without elaborating on the authors' role in the article, so we could only interpret their responses literally, without knowing their exact intent.

> *"The abstract indicates that this paper is on original research..."*
>
> *"It was newly published research, with new information about a previously unexplored topic."*

Sometimes students further explained what they meant, yet we still could not apply the *primary* code. Without explicitly spelling out the authors' role, it remained impossible to determine whether students were making the connections intended from the instruction. Students may have indicated that researchers conducted a study, but it was not clear if the

researchers were also the authors reporting their study. Based on spot checks of student selected articles attached to responses like this, it often turned out that students were looking at review articles.

> *"I determined that this was an original research article because I found that in the abstract that the researchers utilized their own methods..."*
>
> *"This was primarily due to the fact that a research study was conducted demonstrating original data…"*

Other times responses stood out because they did not seem to be aligned with our definition of original. There are multiple meanings of the word "original," and we speculate that students approached article selection thinking about related but different definitions. Some students described uniqueness or novelty. Other times students seemed to be describing location or the origins of their article. Newness was sometimes equated with originality.

> *"I was able to determine if it was a original research article by looking to see if there were more topics like it in web of science but it was the only one so in doing so i decided it was a original"*
>
> *"Making sure that there were no other articles like it"*
>
> *"Because i followed links till i reached the final and original article"*
>
> *"No one has cited their work yet meaning that this is a newly discovered topic and original."*

Finally, we observed reasoning that connected original research to understandings of primary versus secondary sources. In our instruction, we explain that secondary sources, like review articles, can be tricky because they share many of the same contents and characteristics as

original research articles. We distinguish how review articles summarize and synthesize the results of previously published studies to communicate the state of existing research on a given topic. Some students seemed to comprehend this idea through their response, although success at selecting an article was still mixed.

> *"I looked at the research methods and results to ensure that... they were original experiments and not just reports on others' experiments."*
>
> *"I determined this was an original research article as it was about a new study that was conducted. It was not a summary article about someone else's research."*
>
> *"The article also was presenting results found by the scientists, versus providing any sort of interpretation."*

Other students articulated that original articles must maintain a sense of independence or ownership of the research.

> *"...collection and processing of data themselves without using other scientific data other than references."*
>
> *"The article analyzes its own data relating to rotavirus and creates its own conclusions about individuals strains of the virus."*

In a few cases, students explained that original research must not rely on references. Although not entirely sure what was meant, we were surprised at the hard line some students took about original research not including references.

> *"...the authors did not reference off of other peoples work."*
>
> *"...by making sure there are no sources"*

The codes *primary* and *research* that were used in this theme were among the top five most frequently coded. The frequency of this reasoning, however, did not translate to a clear correlation of success among students who used it. Language is a sticking point because we bring such a specific meaning of "original" to original research. We observed confusion with our concept of original versus more commonplace meanings. Further, students who appeared to understand original research conceptually still regularly struggled to correctly select an original research article. This may indicate a need for more emphasis on teaching about primary and secondary sources through a disciplinary lens.

Conclusion

Findings from this study indicate that second-year biology students were highly successful at identifying the correct definition of an original research article from a choice of four definitions. Because students were successful in the pretest as well as the posttest, we suspect that they received previous instruction about the big idea of original research. Teaching definitions is important groundwork, yet it is the most abstract and passive task we asked students to complete, and it doesn't necessarily translate to more direct applications. Our results suggest that, in assessing students' authentic understanding of complex information format concepts, it is important to dig deeper than definitions.

In the next task, students were less successful at correctly selecting an example original research article from a group of four articles of varying formats. This finding indicates that identifying original research articles is harder than it may look at the 30,000-foot view. In this task, we asked students to engage in deeper recognition of original research alongside similar looking but distinct scholarly formats.

In the task of finding an original research article through their own library database search, students also had mixed success. Students in the 2020 dataset were more successful at

selecting their own original research article. These were the students who received in-person support from a librarian, compared with the 2021 students who completed this task without in-person librarian support. This contrast is further compounded by the fact that many more students completed the in-depth IL tutorial prior to the worksheet in 2021, as compared to 2020. This finding further demonstrates how format knowledge can be troublesome for novice learners in the absence of receiving quick feedback from an expert. It may also indicate teaching challenges associated with fully asynchronous learning.

The reasoning students used when describing how they determined that the article they selected was original research emerged in six major themes and was relatively consistent regardless of whether or not students successfully selected an original research article versus another format. Student reasoning frequently hinged on skimming the article contents looking for the core sections of original research articles. Students also commonly pointed to the presence of article characteristics, which is the first step in developing a deeper appreciation of the valuable contextual clues that disciplinary experts use when they read and interpret formats. One of our most interesting findings concerned a misunderstanding in language, specifically the multiple meanings of "original" that students brought to their evaluation when identifying original research articles.

Based on our findings, we have recommendations for teaching IL to undergraduate students in the sciences who are required to engage with and identify primary literature. First, we propose strategically using synchronous and asynchronous IL instruction to maximize the strengths and weaknesses that emerged from our data. Asynchronous instruction may be best used to introduce and clarify high-level definitions and concepts, such as emphasizing the specific meaning of "original" in the context of original research as well as providing more explanation of primary versus secondary sources in the sciences. As undergraduate science

courses often have very structured, content-heavy curricula (Fuselier et al., 2017), asynchronous instruction is an advantageous opportunity to deliver in-depth IL instruction outside of scheduled class times.

Following foundational asynchronous work, paired synchronous instruction with direct librarian support may be best designed by having students test their prior knowledge and receive immediate feedback on collective or individual sticking points. This could include helping students see the limitations of using surface-level evaluations, such as over relying on the presence of article characteristics, especially in isolation. For example, it is a good starting point to notice a label, but it is not enough to solely depend on the label as a novice just learning to navigate scholarly formats. Synchronous instruction also helps to remove the barrier to seeking help that is inherent to asynchronous learning.

Finally, we want to underscore that as a student entering into a discipline, identifying original research articles is harder than it looks and requires a diverse toolbox of skills. We aim to help students build an understanding of the purposes and processes behind scholarly scientific formats to better understand the big picture, in part through more strategic engagement with the text. Our findings suggest that more emphasis on the practical application of identifying formats, coupled with direct, synchronous support from a librarian, makes a positive impact on students' abilities to correctly identify original research articles. Future course design will take these findings into consideration to increase successful outcomes for students. Building upon these findings, future research may employ a similar instruction model to investigate students' abilities to identify critical format types in disciplines outside of biology (i.e., engineering, social science, humanities).The field would also benefit from the development of a clear evaluative model that walks students through complex disciplinary format evaluations, including primary and secondary sources.

Acknowledgements

We are grateful to Laura Soito and Sever Bordeianu for their critical reading of the manuscript.

Disclosure statement

The authors report there are no competing interests to declare.

Notes on contributors

Alyssa Russo is a Learning Services Librarian and Assistant Professor at the University of New Mexico. She earned a Bachelor of Fine Arts from the University of New Mexico and a Master of Library and Information Science from the University of Illinois at Urbana-Champaign.

Amy Jankowski is a STEM Librarian and Assistant Professor at the University of New Mexico. She earned a Bachelor of Arts in Anthropology from the University of Illinois at Urbana-Champaign and a Master of Library Science from Indiana University Bloomington.

Appendix: Codes, Code Descriptions, and Example Student Responses

Code	**Description**	**Example Student Response**
abstract	References the abstract or content of the abstract. May double code with IMRD.	“The abstract indicates that this paper is on original research…”
access	Describes the process of navigating to the article or searching. May include mention of database used.	“I used the pub med article search…”
analysis	Makes specific reference to analysis (may be related to data or content).	“...most data is analyzed by themselves…”
authority	Makes an appeal to authority such as credentials, author summary pages, source reputation, metrics, or author impact.	"the authorship indicated professionals well versed within their field."
authors	Refers to the person/people who created the information. May call out multiple authors.	"More than one author..."

bias	Uses the word "bias."	"It was not slated or biased."
citations	References the presence or absence of citations, sources, or references.	"...the article does cite various other sources..."
compare/deductive	Makes comparison against other information, or deductively describes the article by mentioning what it isn't.	"The article also was presenting results found by the scientists, versus providing any sort of interpretation."
content broad	Makes general reference to the content, text, or information in the article.	"Looking at the contents was how I determined it to be an original research article."
content specific	Quotes or paraphrases content from the article.	"This article also shows some genetic predispositions to obesity by studying the genetics of a certain population."
credibility	Use of the word "credibility" without explaining further.	"...because it is from a credible website."
currency	Refers to how recently information has been published or updated.	"I saw that it was recently published."
data	References the presence or absence of data.	"The methods also appear that this was originally obtained data..."
date	Refers to the date of the information, but does not explicitly connect it to recency.	..." it includes the date of when it was published..."
detail	Characterizes the depth, amount, or volume of detail in the writing.	"Writing is not summarized but very detailed about all processes of the study."
discussion	Refers to the discussion section or mentioned the research findings, discovery, conceptual analysis, conclusions, or future research.	"I determined as such by reading the abstract conclusion which mentioned sampling of genomes and loci."
evidence	Refers to the presence, absence, or type of evidence	"They had information to back up their research."
format	Refers to a specific genre, information type, or type of publication.	"I checked... to see whether it was an article or something else."
formatting	Reference to the article's layout and organization. More general than IMRD.	"Formatted like a research article."

IMRD	Refers to the article's structure of four core sections: Introduction, Methods, Results, and Discussion. Must make specific reference to sectioned structure or list at least three section names; may use synonymous terms.	"The article itself has all of the main components: introduction, methods, results, and discussion."
interest	Expresses interest in the article or the article's subject.	"it seemed to be covering what I was interested."
introduction	References the Introduction section, or introductory background information, literature review, or broader context.	"The authors provide background and rational etc for their study."
label	Refers to the presence or absence of an identifying notation or label.	"...it says "original article" near the article title."
language	Notes specific wording in the article's content.	"It contained the word “demonstrated" and "... identified". These terms convinced me that some type of experiment was being conducted."
length	Mention of how long or short information is.	"This article is relatively short, which is very rare in this case."
librarian	Mention of consulting with a librarian.	"I read the abstract and followed the instructions given to me by the librarian"
metacognition	Articulates awareness and understanding of their learning or thought process.	"I might be incorrect in determining if this is an original research article though."
methods	References the Methods section or the research approaches/process.	"The methods section also outlines how they performed their experiment, step by step."
new	Refers to the subject, topic, findings, or methods as "new."	"It presented new research..."
objective	Refers to the presence or absence of a research question, hypothesis, research aims, goals, objective, or purpose.	"I determined it was an original research article by reading the abstract and finding a research study question"
original	Uses the word "original" without further explanation.	"I saw that it presented its own original information..."
ownership	Says "their own," "its own," or otherwise puts particular emphasis on the authors' ownership of the research.	"The author was Using his own data and research when explaining his theory."

peer review	Refers to "peer review" or the quality control process scholarly journal articles go through prior to publication.	"It had sounded like it was peer reviewed..."
primary	Reasons that the article's authors wrote about a study they conducted.	"The article is written by the person who conducted the research."
publisher	Refers to the organization responsible for disseminating information.	"This article... was published by the National Cancer Institute."
research	Uses the terms "research" or "study" to describe the information.	"because they showed the summary of their research..."
results	References the Results section or the study's data or results.	"...it stated that it had run the experiment and collected the results."
scholarly	Reasons that the article was published in a scholarly journal or through a scholarly conference.	"I also saw that it was published by a peer reviewed journal."
scholarly conversation	Made a connection from the article to the larger evolution of ideas within the scholarly community, or made a reference to the citation metrics.	"...the conclusion that suggested further future research could build upon these results..."
scientific method	Referenced the scientific method.	"I... looked for general concepts of an original scientific study, using the scientific method."
scope	Characterized the extent or range of the article's subject.	"The subject was so niche that it had to have been a primary study."
secondary	Mentioned or described secondary sources that summarize, analyze, interpret, or evaluate primary sources.	"It was not a summary article about someone else's research."
subject	Generally referenced the article's subject area or topic.	"This was a study on wolf fecal matter."
title	Referred to the article's title in reasoning.	"Also, the title is very specific with what gene the research study is talking about."
tutorial	Referred to the BIOL 2410C tutorial.	"I read the abstract using techniques I received via the tutorial."
unclear	Coder is unclear what the reasoning is; reasoning is not specific enough to code more discreetly.	"It met all the criteria of a journal article."
unique	Described the article as novel or unique.	"Making sure that there were no other articles like it."

verification	Claimed to verify the accuracy of the article's contents, or described their process of checking for accuracy.	"The publisher allowed me to determine if the article was valid because I was able to search the publisher and the authors who wrote it. "

References

American Library Association. (2015). *Framework for information literacy for higher education*. http://www.ala.org/acrl/standards/ilframework

Association of College and Research Libraries Science and Technology Section Information Literacy Framework Task Force. (2021). *ACRL Science and Technology Section framework for information literacy for higher education companion document*. https://acrl.libguides.com/sts/STSILFramework

Barkley, M. (2018). The library in the laboratory: Implementing an online library tutorial in a freshman biology lab. *Issues in Science and Technology Librarianship*, *88*. https://doi.org/10.5062/F45B00QH

Borchardt, R., Salcedo, T., & Bentley, M. (2019). Little intervention, big results: Intentional integration of information literacy into an introductory-level biology lab course. *Journal of Biological Education*, *53*(4), 450–462. https://doi.org/10.1080/00219266.2018.1494029

Bransford, J., Brown, A. L., & Cocking, R. R. (1999). *How people learn: Brain, mind, experience, and school.* National Academy Press.

Brante, E. W., & Strømsø, H. I. (2018). Sourcing in text comprehension: A review of interventions targeting sourcing skills. *Educational Psychology Review*, *30*(3), 773–799. https://doi.org/10.1007/s10648-017-9421-7

Bromme, R., Scharrer, L., Stadtler, M., Hömberg, J., & Torspecken, R. (2015). Is it believable when it's scientific? How scientific discourse style influences laypeople's resolution of conflicts. *Journal of Research in Science Teaching*, *52*(1), 36–57. https://doi.org/10.1002/tea.21172

Carroll, A. J. (2020). Thinking and reading like a scientist: Librarians as facilitators of primary literature literacy. *Medical Reference Services Quarterly*, *39*(3), 295–307. https://doi.org/10.1080/02763869.2020.1778336

Ferguson, J. E., Neely, T. Y., & Sullivan, K. (2006). A baseline information literacy assessment of biology students. *Reference & User Services Quarterly*, *46*(2), 61–71. https://doi.org/10.5860/rusq.46n2.61

Ferrer-Vinent, I. J., & Carello, C. A. (2008). Embedded library instruction in a first-year biology laboratory course. *Science & Technology Libraries*, *28*(4), 325–351. https://doi.org/10.1080/01942620802202352

Fuselier, L., Detmering, R. & Porter, T. (2017). Contextualizing and scaling up science information literacy in introductory biology laboratories. *Science & Technology Libraries* 36(2), 135–152. https://doi.org/10.1080/0194262X.2017.1307158

Fuselier, L., & Nelson, B. (2011). A test of the efficacy of an information literacy lesson in an introductory biology laboratory course with a strong science-writing component. *Science & Technology Libraries*, *30*(1), 58–75. https://doi.org/10.1080/0194262X.2011.547101

Gamtso, C. W., & Halpin, P. A. (2018). Tailoring library instruction for non-science majors taking hybrid and online science classes: Student perceptions of information literacy in the virtual environment. *Public Services Quarterly*, *14*(2), 99–118. https://doi.org/10.1080/15228959.2017.1372729

Gehring, K. M., & Eastman, D. A. (2008). Information fluency for undergraduate biology majors: Applications of inquiry-based learning in a developmental biology course. *CBE—Life Sciences Education*, *7*(1), 54–63. https://doi.org/10.1187/cbe.07-10-0091

Greer, K., & McCann, S. (2018). Everything online is a website: Information format confusion in student citation behaviors. *Communications in Information Literacy*, *12*(2), 150-165. http://doi.org/10.15760/comminfolit.2018.12.2.6

Hofer, A. R., Lin Hanick, S., & Townsend, L. (2019). *Transforming information literacy instruction: Threshold concepts in theory and practice*. Libraries Unlimited.

Hoskins, S. G., Stevens, L. M., & Nehm, R. H. (2007). Selective use of the primary literature transforms the classroom into a virtual laboratory. *Genetics*, *176*(3), 1381–1389. https://doi.org/10.1534/genetics.107.071183

Howard, K. N., Stapleton, E. K., Nelms, A. A., Ryan, K. C., & Segura-Totten, M. (2021). Insights on biology student motivations and challenges when reading and analyzing primary literature. *PLOS ONE*, *16*(5), e0251275. https://doi.org/10.1371/journal.pone.0251275

Hubbard, K. E., & Dunbar, S. D. (2017). Perceptions of scientific research literature and strategies for reading papers depend on academic career stage. *PLOS ONE*, *12*(12), e0189753. https://doi.org/10.1371/journal.pone.0189753

Klucevsek, K. (2017). The intersection of information and science literacy. *Communications in Information Literacy*, *11*(2), 354-365. https://doi.org/10.15760/comminfolit.2017.11.2.7

Klucevsek, K. M., & Brungard, A. B. (2016). Information literacy in science writing: How students find, identify, and use scientific literature. *International Journal of Science Education*, *38*(17), 2573–2595. https://doi.org/10.1080/09500693.2016.1253120

Lammers, A., Goedhart, M. J., & Avraamidou, L. (2019). Reading and synthesising science texts using a scientific argumentation model by undergraduate biology students. *International Journal of Science Education*, *41*(16), 2323–2346. https://doi.org/10.1080/09500693.2019.1675197

Lantz, C., & Dempsey, P. R. (2019). Information literacy strategies used by second- and third-year biology students. *Issues in Science and Technology Librarianship*, *92*. https://doi.org/10.29173/istl13

Lindquester, G. J., Burks, R. L., & Jaslow, C. R. (2005). Developing information fluency in introductory biology students in the context of an investigative laboratory. *Cell Biology Education*, *4*(1), 58–96. https://doi.org/10.1187/cbe.04-07-0046

Nelms, A. A., & Segura-Totten, M. (2019). Expert–novice comparison reveals pedagogical implications for students' analysis of primary literature. *CBE—Life Sciences Education*, *18*(4), ar56. https://doi.org/10.1187/cbe.18-05-0077

Park, S., Mardis, L. A., & Jo Ury, C. (2011). I've lost my identity – oh, there it is … in a style manual: Teaching citation styles and academic honesty. *Reference Services Review*, *39*(1), 42–57. https://doi.org/10.1108/00907321111108105

Petzold, J., Winterman, B., & Montooth, K. (2010). Science seeker: A new model for teaching information literacy to entry-level biology undergraduates. *Issues in Science and Technology Librarianship*, *63*. https://doi.org/10.5062/F4ZW1HVJ

Porter, J. A., Wolbach, K. C., Purzycki, C. B., Bowman, L. A., Agbada, E., & Mostrom, A. M. (2010). Integration of information and scientific literacy: Promoting literacy in undergraduates. *CBE—Life Sciences Education*, *9*(4), 536–542. https://doi.org/10.1187/cbe.10-01-0006

Rose-Wiles, L., Glenn, M., & Stiskal, D. (2017). Enhancing information literacy using Bernard Lonergan's Generalized Empirical Method: A three-year case study in a first year biology course. *The Journal of Academic Librarianship*, *43*(6), 495–508. https://doi.org/10.1016/j.acalib.2017.08.012

Schreier, M. (2012). *Qualitative content analysis in practice.* SAGE.

Shannon, S., & Winterman, B. (2012). Student comprehension of primary literature is aided by companion assignments emphasizing pattern recognition and information literacy. *Issues in Science and Technology Librarianship*, *68*. https://doi.org/10.5062/F4TB14TS

Stengel, A., Stanke, K. M., McPherson, M. R., & Drijber, R. A. (2021). Virtually engaging students through collaborative investigation of scientific literature, a case study. *Natural Sciences Education*, *50*(1), e20051. https://doi.org/10.1002/nse2.20051

Tsunekage, T., Bishop, C. R., Long, C. M., & Levin, I. I. (2020). Integrating information literacy training into an inquiry-based introductory biology laboratory. *Journal of Biological Education*, *54*(4), 396–403. https://doi.org/10.1080/00219266.2019.1600569

University of New Mexico Office of Institutional Analytics. (2022) Official enrollment reports. University of New Mexico. https://oia.unm.edu/facts-and-figures/official-enrollment-reports.html

Wineburg, S. S. (1991). On the reading of historical texts: Notes on the breach between school and academy. *American Educational Research Journal*, *28*(3), 495–519. https://doi.org/10.2307/1163146

Wineburg, S., & McGrew, S. (2017). Lateral reading: Reading less and learning more when evaluating digital information (SSRN Scholarly Paper ID 3048994). *Social Science Research Network*. http://doi.org/10.2139/ssrn.3048994