An Adapted Journal Club Approach
Integrating Contemporary Literature Into the Undergraduate Classroom

By Melissa Eslinger, Sydney Alekseyev, and Helen Schroeder

Students must be able to evaluate primary literature, yet few options exist within the undergraduate curriculum to develop the necessary skills. In this article, we offer an adapted journal club that provides students opportunities to critically analyze selected research articles, emphasizing scientific communication, critical thinking, and practical application of coursework. We include the primary instruments of the adapted journal club, teaching tips, and guided implementation recommendations, including tools to pre-designate student roles to examine specific aspects of the article. Using their preclass homework as a guide, students present their respective portions to the class as the class gains a collective understanding of the research design, experimental approach, and relative merits. This student-centric learning approach achieved significant gains in scientific literacy. Our data show a 37% increase in student abilities to analyze study design, a 61% gain in discerning primary from secondary sources, and gains of between 61% and 76% in the confidence to lead content-specific scientific discussions. We present this approach and suggest that grades, self-assessments, and surveys illustrate the benefits of the adapted journal club for the undergraduate learning experience.

Effective and accurate communication is a critical skill for future scientists to develop throughout their education and training. A useful method for such instruction is the implementation of active learning strategies within the classroom, including opportunities for class discussions, writing exercises, and reading reflections (University of Connecticut, n.d.; University of Minnesota, n.d.). While these teaching methods seek to guide undergraduate students from being passive consumers to becoming generators of knowledge, few avenues deliberately focus on students’ digestion and interpretation of primary scientific literature.

Our initial goal was to develop a robust tool to promote scientific literacy in undergraduates and complement conventional classroom content. One pragmatic method to achieve this objective is a journal club, a collaborative effort undertaken by groups of academics within a certain discipline to remain abreast of contemporary research and disseminate knowledge in a communal environment (Topf et al., 2017; Biswas, 2011). Journal clubs are often used in medical training (McLeod et al., 2010) to translate classroom content into clinical or research applications or to leverage social media in ways that will stimulate interactive discussion (Aronson, 2017). Research communities often implement such meetings as compulsory measures to encourage multidisciplinary discussion among scientists within specific disciplines during graduate studies. Typically, this translates to someone presenting a brief summary and entertaining questions from the audience regarding the experimental design or methods or a deeper interpretation of the results (Bauer, 2015). These skills would be extremely valuable to rehearse early in academic training, yet few opportunities exist for the incorporation of journal clubs into the undergraduate curriculum.

Several groups are beginning to practice various aspects of undergraduate journal clubs to promote enthusiasm through exposure to contemporary scientific literature (Clark & Rollins, 2014; Smith & Wood, 2016). Incorporating literature across disciplines is the cornerstone of these and other works (Breakwell, 2003; Krontiris-Litowitz, 2013), but such approaches have induced frustration for early-career trainees. This frustration can be addressed by providing students a model in which they generate their own abstract on a provocative topic, drawn from primary literature (Clark & Rollins, 2014). Others have used journal clubs as separate seminars to not only promote the development of communication skills but also improve students’ confidence in applying primary scientific literature (Sandefur & Gordy, 2016).

The almost-universal introduction
of technology to the undergraduate population brings immediate access to large amounts of information. Indeed, due to an overabundance of both credible and noncredible sources accessible to anyone with internet access, search results can quickly influence the public perception of science and contribute to misinformation (Thaler & Shiffman, 2015). Thus, information must be critically analyzed and carefully weighed to establish credible evidence in support of claims in order to manage misconceptions and prevent bias. Rather than focusing solely on technological advancements, it is imperative to train students to discern fundamental concepts and evaluate the relative merits from which claims about health and societal impacts are made (Smith & Wood, 2016; Redfield, 2012). The implementation of active learning strategies (Freeman et al., 2014) illustrates that information is best recalled when taught through realistic scenarios or examples (Tokuhama-Espinosa, 2010).

There are numerous postulated methods by which this could occur, with historical approaches ranging from individual student presentations of comprehensive analysis (Sawhney, 2006) and expert discussion panels engaging with student presentations over dinner (Kalra, 2016) to two-way virtual dialogues between authors and students (Lin & Sherbino, 2015). Communal learning is a major part of this push, with trends toward peer-to-peer instruction and learning through teaching as elements in both undergraduate and postgraduate levels of education (Dede, 2005; Topf et al., 2017). As such, a key goal of undergraduate scientific education (American Association for the Advancement of Science, 2011) is to develop a community of scholars who can actively integrate abstract concepts through real-world examples, thus shifting learning toward the interpretation of new information rather than reliance on expert opinion.

We wanted to improve retention of scientific information by engaging students with real-world situations (Henricks-Lepp, 2016) that are emerging within the science community. While individual students have a host of unique learning styles, the idea was to actively include auditory, kinesthetic, and visual aspects in the effort. Moreover, studies suggest that students prefer active classroom engagement and that such strategies promote increased conceptual understanding (Bonwell & Eison, 1991). Systematic approaches grounded in small-group dynamics, those involving peer review or interactive role playing, and learning strategies that range from simple to complex (O’Neal & Pinder-Grover, n.d.) are particularly useful for the long-term retention of ideas (McKeachie et al., 1986). This transitions the teacher from lecturing to guiding discussions (Andriotis, 2017), as students either collaborate in small groups or complete individual work or reflections (University of Minnesota, n.d.). Such changes are not without challenges, as some instructors are uncomfortable transitioning classroom control to students and it can be difficult to encourage contributions by all students rather than a select few (Bonwell & Eison, 1991).

Limited defined models exist by which undergraduate journal clubs can be used with defined individual contributions on a regular basis. A balance needs to exist between

<table>
<thead>
<tr>
<th>Objective</th>
<th>Implementation</th>
<th>Assessment mechanism</th>
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<tbody>
<tr>
<td>Develop problem-solving skills.</td>
<td>Analyze and mirror patterns in research across the discipline.</td>
<td>Preclass written analysis; in-class oral explanation of designated figure</td>
</tr>
<tr>
<td>Develop scientific communication skills (oral and written).</td>
<td>Prepare written preclass analysis of paper based on pre-designated roles and figures. Present in-class oral presentation.</td>
<td>Individual preclass analysis; written communication Ability to identify the experimental technique used, define its purpose, and describe the results in class as part of a group Ability to ask/answer questions by peers</td>
</tr>
<tr>
<td>Promote critical thinking and analysis of literature.</td>
<td>Conduct analysis of a specific figure.</td>
<td>Ability to articulate experimental approach and validity in both verbal and oral forms</td>
</tr>
<tr>
<td>Apply scientific methods.</td>
<td>Have students participate in preclass analysis and in-class discussion.</td>
<td>Ability to describe research question and experimental design and relate results to hypothesis</td>
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</tbody>
</table>
individual student mastery through presentation and collective group understanding. Undergraduate students are early in the process of developing their scientific literacy skills, in contrast with authors or researchers within their respective field who have years of experience with consuming and producing primary research. We therefore sought to determine a systematic approach that can synergistically leverage course content and encourage individual scientific literacy and stimulate critical thinking through group discussions of complex topics (Table 1). We sought to fill this training deficiency by designing an adapted journal club, which included a preclass assignment, with clearly defined questions and student responsibilities, that would shape the in-class discussions. Events were designed for students to enhance their individual competencies in tandem with gaining experience through scientific dialogue with the group.

We developed the journal club process in our undergraduate genetics course, leveraging primary literature as a venue for students to analyze scientific advances that were complementary to the foundational components of the course. Within our pilot study, seven lessons were dedicated to the refinement of the journal club implementation process (described in Table 2). Our adapted journal club clearly defined student roles in advance (Appendix A online) and provided a common instrument to guide their written analysis (Appendix B online) and in-class discussion (Appendix C online). The analysis incorporated several aspects of the medical school curriculum—stating the research question, describing the methods used, summarizing the results, and preparing written analyses—all of which were designed to improve both audience interaction and precise communication of findings (Schwartz et al., 2007; Atzema, 2004). Additionally, this direction and guidance divided responsibilities among students to decrease intimidation for the relatively inexperienced audience as they communicated.

### TABLE 2

<table>
<thead>
<tr>
<th>Timing</th>
<th>Who</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before class</td>
<td>Instructor</td>
<td>Select primary article related to course theme.</td>
</tr>
<tr>
<td></td>
<td>Students</td>
<td>Identify student roles for preclass analysis.</td>
</tr>
<tr>
<td></td>
<td>Students</td>
<td>Identify student roles for in-class discussions.</td>
</tr>
<tr>
<td></td>
<td>Students</td>
<td>Introduce theme in lesson prior to journal club.</td>
</tr>
<tr>
<td></td>
<td>Students</td>
<td>Complete written preclass analysis based on pre-designated role.</td>
</tr>
<tr>
<td></td>
<td>Students</td>
<td>Prepare oral explanation of designated figure or role.</td>
</tr>
<tr>
<td></td>
<td>Students</td>
<td>Coordinate with the group as needed.</td>
</tr>
<tr>
<td>During class</td>
<td>Instructor</td>
<td>Provide initial instructions (2–3 minutes).</td>
</tr>
<tr>
<td></td>
<td>Students</td>
<td>Allow the group leader/assistant to direct journal club.</td>
</tr>
<tr>
<td></td>
<td>Students</td>
<td>Provide guidance and questions during the presentation as needed.</td>
</tr>
<tr>
<td></td>
<td>Students</td>
<td>Provide oral explanation of designated figure(s) or context.</td>
</tr>
<tr>
<td></td>
<td>Students</td>
<td>Provide necessary background or context of study.</td>
</tr>
<tr>
<td></td>
<td>Students</td>
<td>Describe how the figure supports the research question.</td>
</tr>
<tr>
<td>After class</td>
<td>Instructor</td>
<td>The assessment team will score student presentations and participation.</td>
</tr>
<tr>
<td></td>
<td>Students</td>
<td>Review assessment team scores from in-class presentations.</td>
</tr>
<tr>
<td></td>
<td>Students</td>
<td>Grade written submissions.</td>
</tr>
<tr>
<td></td>
<td>Students</td>
<td>Enter grades for preclass and in-class portions.</td>
</tr>
<tr>
<td></td>
<td>Students</td>
<td>Prepare for the integration of journal club as an extension of the next lesson.</td>
</tr>
<tr>
<td></td>
<td>Students</td>
<td>Raise remaining questions on the theme at the following lesson.</td>
</tr>
<tr>
<td></td>
<td>Students</td>
<td>Identify conceptual ties from journal club to the following lesson.</td>
</tr>
</tbody>
</table>

*Note.* Students are encouraged to have a prominent role in both discussions and preparation.
findings without overinfluencing discussions toward one extreme. In this manner, critical thinking and applied knowledge can be increased without students becoming overwhelmed by new material for which they have minimal or no frame of reference. This approach has an added benefit of training new scientists in their future roles as reviewers and panel members, in which they will ask questions and synthesize findings with an analytical yet informed lens. Our hypothesis was that this adapted journal club format would improve foundational knowledge through an application-based approach and that this approach would lead to measurable gains attributable to instruction. Using surveys, intrinsic course measures, and student feedback, we examined the success of the journal club tool within a second-year genetics course. We present this adapted journal club process, which is intended for use in the undergraduate scientific curriculum, to address training needs, improve scientific literacy, and promote oral communication skills.

**Methods**

**Student population**

Second-year undergraduates majoring in life science \( (n = 36) \) were enrolled in a one-semester genetics course. Students had completed one year of general chemistry and were either concurrently enrolled or had completed one semester of advanced biology. The course was executed across 30 lessons that lasted for 75 minutes each. There were no separate laboratory exercises, and the journal club therefore provided a pragmatic alternative for introducing students to experimental techniques. Student resources included the textbook (Sanders & Bowman, 2019) and electronic versions of all pre-assigned articles. Student data were collected according to the internal Human Research Protection Program (HRPP 19-044).

**Article selection to support curriculum**

Faculty selected articles to address multiple aspects of genetics-related topics. These topics were part of an iterative sequence in which a traditional, faculty-led lesson preceded the journal club to provide foundational background knowledge. For example, a research article regarding epigenetics of a select disease would follow a class session on the mechanics of methylation or acetylation. With some basic understanding, students prepared individual written summaries (Appendix B), which were submitted at the beginning of the journal club. Overall, seven articles were used during the semester in distinct journal club–designated lessons.

**Journal club mechanics**

The journal club contained preclass and in-class portions, which were graded separately. The individual steps are summarized in this section, along with student requirements. For our purposes, the preclass written analysis ensured a baseline level of background knowledge for the students prior to class and accounted for a majority of the assigned points (30), while the presentation points (10) were primarily associated with peer assessments during class. This peer assessment worked well with our institutional developmental model, in which students routinely provide and receive performance feedback when executing challenging experiences as they reflect on learning new knowledge (United States Military Academy, 2018).

The journal club proceeded in three steps. First, students were assigned to specific teams (Appendix A). Students rotated through predesignated roles for each journal club so they would work with different peers and have equal opportunities to take on leadership and supporting analysis roles. The distribution of figures across the cohort decreased the burden on any individual student.

The second step included student completion of the preclass written analysis. This analysis (Appendix B) was completed individually and due at the beginning of the corresponding class period. Focal points included prompts regarding background information, methods, results, and conclusions. This analysis represented the format of a scientific paper but, with an assigned point value, encouraged students to prepare and arrive with a baseline understanding so they could contribute meaningfully to the discussions.

The third step involved in-class presentations and discussions of the designated article. Following an initial time when the group leader and assistant provided instructions to the class (approximately 2 minutes), groups finalized their plan of action and began with the background material (approximately 5 minutes). The paper was projected on the screen for the class. The remainder of the class time was devoted to groups presenting their figures and responding to questions from the class. The group leader ensured that students remained on task and all figures were presented in the class period.

Students were scored by the predesignated assessment team using the provided rubric (Appendix C). The in-class scores were tabulated by the instructor and assigned as the
average of those determined by the student assessment team. The grade for the assessment team was based on the quality and thoroughness of their assessment, as described in Appendix C. While this discussion was primarily student led, faculty interjected to provide context when additional background was needed for students to understand a figure or its relevance to the research question.

**Indirect assessment: Student surveys**

Pre- and postcourse surveys were submitted during the first and final lesson by all students in this pilot study cohort \( (n = 36) \). The survey had two components: The first was an individual self-ranking (score 0 [low] to 8 [high]) on their ability to understand and apply the scientific process. The second part contained open-ended questions on the merits of the journal club process and educational approaches to learning.

**Results**

The primary course objective was for students to develop problem-solving skills and extract and use genetic information in tandem with an awareness of the bioethics of this rapidly evolving field. To support this goal, the assessment strategy examined students’ abilities to analyze and interpret complex data from the scientific community though the use of graded journal clubs and pre- and postcourse surveys. Self-assessments on the relative ability of each student to apply the scientific method in the context of specific genetics-related content illustrated the marked progression of skills; moreover, the students commonly stated that was the most enjoyable and important part of the course (Table 3). Indeed, these self-assessments indicated that students preferred this approach to learning and benefited significantly from the skills that were practiced throughout the journal club.

A key component of effective scientific communication is the ability to convey meaningful information to diverse audiences in oral and written forms. We first measured this through a written analysis (30 points each across 7 unique journal clubs) and then through in-class presentations (10 points each for 7 clubs), which together represented 30% (280/920) of the final course average. Students demonstrated functional proficiency by preparing written responses to the research articles, with average scores ranging from 84% to 99% (+/− 3.11 standard deviation) across

### TABLE 3

**Student self-assessment comparison.**

<table>
<thead>
<tr>
<th>Q1. I am confident in my abilities to:</th>
<th>Preclass mean</th>
<th>Postclass mean</th>
<th>( p ) value</th>
<th>Norm gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>a Integrate data to make scientific conclusions.</td>
<td>5.39</td>
<td>6.37</td>
<td>**</td>
<td>0.38</td>
</tr>
<tr>
<td>b Analyze scientific research design.</td>
<td>5.50</td>
<td>6.43</td>
<td>***</td>
<td>0.37</td>
</tr>
<tr>
<td>c Appreciate differences between association and causation.</td>
<td>5.67</td>
<td>6.51</td>
<td>**</td>
<td>0.36</td>
</tr>
<tr>
<td>d Read and understand primary scientific literature.</td>
<td>5.67</td>
<td>6.40</td>
<td>**</td>
<td>0.31</td>
</tr>
<tr>
<td>e Distinguish knowledge from primary and secondary sources.</td>
<td>5.89</td>
<td>7.17</td>
<td>***</td>
<td>0.61</td>
</tr>
<tr>
<td>f Evaluate hypotheses using appropriate tests.</td>
<td>5.50</td>
<td>6.03</td>
<td>**</td>
<td>0.21</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Q2. I am confident to lead scientific discussion on:</th>
<th>Preclass mean</th>
<th>Postclass mean</th>
<th>( p ) value</th>
<th>Norm gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>a Bioethics.</td>
<td>3.64</td>
<td>6.77</td>
<td>***</td>
<td>0.72</td>
</tr>
<tr>
<td>b Gene editing.</td>
<td>3.69</td>
<td>6.86</td>
<td>***</td>
<td>0.73</td>
</tr>
<tr>
<td>c Bioinformatics.</td>
<td>2.81</td>
<td>5.97</td>
<td>***</td>
<td>0.61</td>
</tr>
<tr>
<td>d Transmission genetics (Mendelian &amp; non-Mendelian).</td>
<td>3.42</td>
<td>6.51</td>
<td>***</td>
<td>0.68</td>
</tr>
<tr>
<td>e Genetic counseling.</td>
<td>2.58</td>
<td>6.71</td>
<td>***</td>
<td>0.76</td>
</tr>
</tbody>
</table>

**Note.** Students ranked their individual proficiency for scientific analysis and abilities to lead discussions on a scale from 0 (low) to 8 (high) for each question listed in the table. Mean reflects the average of pre- and postcourse student self-assessments \( (n = 36) \). \( p \) values reflect students’ \( t \)-test, 1-tailed, paired (*\( p < 0.05; ** p < 0.005; *** p < 0.0005 \)). Normalized gain is \( (\text{post} - \text{pre})/(8 - \text{pre}) \).
the seven journal clubs. Performance in general improved with subsequent journal clubs. Top-tier students—those averaging 90% or higher across all of the preclass analyses (median 94.9%, range 90.4%–98.6%, n = 27)—performed at a higher level during the in-class presentations (94.7% average), as measured by the student assessment teams. In comparison, students averaging below 90% across the preclass analyses averaged 3.6% lower (p = 0.03) on the in-class portions. Content proficiency was compared to student performance on comprehensive problem sets, used as exam equivalents, requiring independent research and demonstrable written synthesis of related material. Averages mirrored the journal club trends, 82% and 94%, which also suggested improved synthesis and communication skills. In addition to grades, student surveys supported the belief that foundational knowledge increased, as did students’ confidence in their ability to lead scientific discussions (Table 3).

Critical thinking is characterized by the integration of knowledge and skills from multiple disciplines. The collaborative nature of the journal clubs afforded students numerous opportunities to examine applications of course content across diverse themes. Student surveys suggested that they progressed from cursory readers of literature to deliberate, more methodical analysts of data with an “ability to synthesize and present information to a wider audience” (Figure 1) and integrate data to recognize conceptual relationships (Table 3).

The open-ended survey prompts provided insights into the student perspective on the journal club (Figure 1). Responses suggested that the journal club was beneficial for students’ comprehension of the course material and, moreover, provided practice in analytical skills that are relevant to all STEM disciplines. Students who expressed initial reservations with the journal club process were required to overcome challenges associated with scientific writing by working past an initial learning curve. The iterative practice of teaching their peers further enhanced student analytical skills, in addition to increasing their confidence in their ability to discern and present primary literature without becoming overwhelmed.

Students also completed pre- and postcourse enumerative assessments of their scientific abilities and their skills in leading discussions on specific course-related themes. This self-assessment was collected during the first and last lessons of the course, and students ranked themselves on a scale of 0 to 8. The average normalized gains [(postcourse – precourse)/(100% – precourse)] measured the learning gains against the knowledge not present at the beginning of the course (Coletta et al., 2007); these gains appear in Table 3. The overall analytical skills and scientific literacy probed by Question 1 resulted in an average sum of 33.6 ± 4.5 (mean ± SD) precourse, with a maximum possible value of 48 (8 points across 6 questions). The postcourse sum increased to a total of 38.8 ± 2.3, equating to a relative gain of 15.5%. We considered whether students could distinguish primary from secondary sources. Our survey suggested that this was the largest gain across Question 1 (Table 3, Question 1e). The goals of integrating data and analyzing research design achieved normalized gains of 0.38 and 0.37, respectively. Likewise, there was a gain of 0.21 in students’ reported abilities about assessing the underlying statistical tests used in the papers.

Focusing on oral communication skills, Question 2 prompted students to identify their gains with respect to confidence in presenting or leading discussions. These results illustrated a significant increase when compared to the precourse average sum of Question

FIGURE 1

A sampling of students’ comments on the journal club process in response to open-ended survey prompts.

1. My ability to analyze information has gotten exponentially better. I am much more confident reading figures/graphs and understanding information in scientific journals/articles. Because of this course, I feel much more prepared and confident in analyzing scientific information in the future.

2. I really liked the journal clubs. I feel as if I have developed crucial skills with respect to reading and understanding scholarly research. I also developed in my ability to synthesize and present information to a wider audience.

3. Although I always dreaded presenting, I think the journal clubs were really important. Knowing the material enough to explain it gave me a lot of practice in public speaking.

4. It was very nice to see how I progressed in terms of understanding and ease of reading from the first to the last (journal club). I would say it would prove beneficial to keep as part of the curriculum.

5. Journal clubs. This is hands-down the most beneficial activity to us as pre-med students. This gave introductory exposure to scholarly journals to us, and it made us more proficient in understanding scholarly literature.

Note. Representative responses are shown (n = 36).
2 (a–c), which was 15.8 ± 5.6 points, with a maximum score of 40 in this instance reflecting 5 questions with 8 points each. The end-of-course responses increased to 32.8 ± 2.1 points, equating to an average relative increase of 106%. Specifically, there were gains of more than 0.70 in bioethics, gene editing, and genetic counseling, with gains of more than 0.60 achieved for bioinformatics and transmission genetics (Table 3). These data suggest that students achieved measurable learning gains and met the analytical and scientific communication objectives described in Table 1.

**Discussion**

The mechanism of supplementing instruction with contemporary primary literature is not novel, but the consistent application and integration of it is worth consideration. This learning approach mimics the skills that emerging scientists and researchers will need in their continued developmental and educational paths. Within active learning strategies, reducing student apprehension is a large concern, with the aim of balancing participation and mitigating fear or fatigue (Eddy et al., 2015). This balance is often accomplished by communicating behaviors that reaffirm learning (Ellis, 2000, 2004) and incorporating specific, guided tools or prompts that lower anxiety (Bell & Kozlowski, 2008). Although most journal club students in our study had completed a previous project that assessed a primary article of their choice (Eslinger & Kent, 2018), this course offered the first opportunity for students to engage with unfamiliar, interdisciplinary literature at a rapid pace. We designed and tested this adapted journal club approach with the goals of developing students’ problem-solving skills to emphasize those related to scientific communication, critical thinking, and practical applications of coursework (Table 1) using the tips for implementation shown in Table 2.

Historically, the format of a journal club involves one or two students presenting the analysis of a paper in its entirety, relying heavily on a small number of students to perform the necessary analysis. This model is somewhat impractical when directly applied to early trainees, who may lack a shared foundational understanding relevant to the paper of interest. Moreover, some students naturally adopt a passive role, and the benefits predominantly favor those assigned to lead discussions. Aronson (2017) suggests that incentivizing group participation can be accomplished by tailoring a topic to the interests of the group. While this suggestion is intriguing, we sought to focus student discussions by selecting journal club topics that mirrored lessons recently covered in students’ genetics course. In doing so, we sought to provide a common framework and support students through their initial discomfort. We designated specific shared responsibilities to focus student effort and decrease the anxiety that may be experienced upon assigning a student to prepare an analysis of the entire paper. A secondary benefit to predesignation is the instructor’s ability to vary the groups, so students interact and serve in new capacities in subsequent iterations and improve their collaborative skills.

Distilling primary literature can be challenging, even for experienced scientists. Indeed, oral and written analytical skills require deliberate practice. Our adapted approach (Table 1) leads to the cultivation of analytical skills first with a faculty primer that provides common understanding of foundational knowledge through lesson-based content, which is then expanded on as students independently analyze a specific aspect of a contemporary research group’s work (Table 2). Students then demonstrate their understanding during class as they complete their clearly defined objectives and ideally remain engaged throughout the duration of the discussion.

Qualitatively, students were initially uncomfortable with the newness of this approach. Direct measures of the individual preclass analyses and in-class group presentations as assessed by grades illustrate the improvement of students’ ability to tease apart the scientific design aspects of the study and determine the relevance of the results in the context of the field of genetics. Indirect assessments as evaluated by student surveys suggest that the journal club process was one of the most important and favored aspects of the entire course. Together, these data suggest that undergraduate students can incorporate and achieve learning gains through deliberate analysis of contemporary literature. While we present the results from an initial pilot study in a genetics course, one could extend this analytical process for its adoption across the scientific curriculum to not only improve foundational knowledge but also enhance analytical skills in reading and understanding primary literature.

Scientific literacy extends to oral communication skills. It is worth noting that instructors can remind students to mentally prepare succinct comments before their talks and direct the audience to the basics or provide context if they or the audience is unfamiliar with the topic. This short summary affords practice in scientific conveyance and brevity. Encouraging discussion on validity (statistical in-
terpretation, conflict of interest, etc.) and examining the relevant literature and citations for supporting materials can help with explaining unfamiliar assays or approaches.

Although it is challenging to quantitatively measure scientific literacy, we developed the primary instrument to meet the objectives (Table 1), teaching tips (Table 2), and guided implementation steps (Appendices A–C online) within this study. We hypothesized that this process would generate measurable gains in students’ abilities to analyze data and communicate results. As shown in Table 3, individual student proficiencies for scientific analysis achieved gains between 31% and 38%, while abilities to discern primary from secondary sources showed a gain of 61%. Notably, self-reported student confidence in their ability to lead discussions on genetics-related content increased between 61% and 76%. While the journal clubs pushed students outside of their comfort zones, grade proficiency and student self-assessments (Table 3 and Figure 1) demonstrate that measurable gains were obtained, further indicating that such an approach is feasible in an undergraduate classroom. It would be intriguing to further correlate which components of the journal club instruments are the most critical to supporting scientific literacy, which itself is difficult to define objectively. Nonetheless, our data suggest that the adapted journal club approach is a useful tool to promote scientific literacy and oral communication skills in the undergraduate classroom, in addition to enhancing content acquisition from the lessons.

While we are fortunate to be at an institution that has compulsory attendance and an assignment compliance model, the practicality of this journal club process can be universally applied. For our undergraduate sophomores, the benefit of iterative exposure to scientific literature was enhanced insight into the process of science and an improved ability to think like a scientist and assess others’ work as they engaged with unfamiliar literature at a rapid pace. The rotation of research topics and roles during each journal club exposed students to various components of collaborative teams. Together, papers from a spectrum of course themes supported the integration of contemporary research within the discipline, bridging conceptual links with foundational knowledge from their textbooks and lessons. While we have currently piloted the adapted journal club in only one course, we anticipate extending similar threads into other life science majors’ coursework. Preliminary data suggest that this student-centric learning approach contributed to significant gains in functional proficiency. Whether these trends permeate subsequent courses remains to be seen, but the foundational skills are present to assist their undergraduate progression across disciplines.

**Conclusion**

Supplementing coursework with primary scientific literature is not itself novel, but the iterative integration of contemporary applications is worth consideration. This active learning approach mimics the skills that emerging scientists and researchers will need in their continued developmental and educational paths. Beyond exposure to the mechanics of asking and answering probing scientific questions, this practice forced students to identify the types of questions reviewers or they themselves should ask when critically analyzing literature covering a variety of disciplines. This synergistic approach fosters skills important to future clinicians and researchers while cultivating higher-order cognitive progression and complex problem-solving skills. The integrated journal club experience presents a structure for introducing and using primary literature to both enhance basic scientific knowledge and demonstrate practical applications of the research process, which will help students advance their research careers.

**Acknowledgments**

We acknowledge the support of the Department of Chemistry & Life Science, Dr. Jason Hoppe, and the West Point Writing Center.

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