REVIEW
Making Primary Literature Come Alive in the Classroom

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By the time young scholars graduate college, they are expected to be prepared for their career. The knowledge that they have gained during their undergraduate education is assumed to prepare them for their future occupation. Understanding primary academic literature is absolutely imperative for scientists who are expected to be able to read, understand, explain, and incorporate literature into their work. Unfortunately, many new graduates are only exposed to traditional learning methods such as textbook readings, lectures, or slide shows about primary literature. It is important that while in college, students learn about the rich content of the literature that serves as the foundation for their respective fields. We review methods for integrating primary literature into the classroom and separate them into three components including (1) introduction to the literature, (2) enhancement of literacy and comprehension, (3) and humanizing the literature. These methods of teaching and learning are far more captivating than simply memorizing facts for a test. The brilliance of these methods is that they can be completed within one class time or throughout a semester. The goal is to help students become comfortable with literature, which does not have to be restricted by any time frame. It is our hope that this review of existing tools and ideas provided will help set students up for success in their field. They allow students to practice knowing and using primary literature while requiring students to be active participants in scientific discovery related to their future occupation.

Key words: science literacy; education; undergraduate education; neuroscience education; CREATE; Jigsaw

Neuroscience professionals are expected to be able to read, understand, and apply the ideas in primary literature. However, undergraduate neuroscience students typically learn about primary literature through delivery formats such as lecture, lab experiences, or textbooks leaving little or no direct experience with original research in a laboratory setting (Becker, 2005; White et al., 2013; Willard and Brasier, 2014), and only a small number of students have the opportunity to publish literature during their time as undergraduate students. Benefits of a primary literature infused undergraduate curriculum include positive outcomes such as facilitation into graduate studies (Kozeracki et al., 2006), improved confidence with scientific terminology and methods (Willard and Brasier, 2014), and enhanced student engagement as analytical consumers of literature (Hoskins et al., 2007). Additionally, engaging education is essential for enrolling and maintaining undergraduate neuroscience students (Ullrich et al., 2012). The purpose of this paper is to present a three-step pedagogical framework for immersion of primary literature in the undergraduate neuroscience curriculum. Steps include: (1) introduction to primary literature, (2) tools for enhancement of literacy and comprehension, (3) and humanizing the literature.

1. INTRODUCING THE LITERATURE

The traditional use of textbooks in the classroom seems to have surpassed its glory days as the main contributor of information. More hands-on, real world experiences are being sought as a means of teaching in the classroom. Exposure to authentic science can be provided by guiding students through primary literature which provides direct access to science and provides flexibility of course design because literature can be conveniently added while the course is underway (Harrington et al., 2015). Students may receive varied exposure to primary literature before entering any particular class, and it is prudent to make no assumptions that students know where to locate pertinent literature.

There have been proven benefits to student collaboration in the classroom compared to individual work such as a deeper level of learning, longer retention of information, and improvement in team work communication skills (Oakley et al., 2004).

One way to acclimate students to primary literature involves presenting student groups with an investigative, think-tank style problem solving task using the following prompt: “Imagine that your group has been asked to write a chapter for a high school neuroscience textbook using primary literature. Use your group knowledge, the internet, and network with other groups in your class to answer the following questions:

1) What is primary literature?
2) Why is it important to cite primary literature in your textbook chapter?
3) How can you access and retrieve primary literature?
4) What are databases?
5) What are journals?
6) What is peer-review?
7) How is primary literature different from information obtained from TV, blogs, social media, and other media?
8) How is primary literature used to generate textbooks?

Next, groups can come together to compare results from the think-tank task with instructor input and advice. The next step of the task requires students to determine gaps in their knowledge of access and retrieval of primary literature with the prompt:

“Create a PowerPoint file with instructions for accessing and retrieving primary literature. Construct the file as if the reader is someone who has never accessed or retrieved primary literature. Include the following terminology in your

instructions: databases, journals, primary literature, and search." Students can take turns presenting their instructions to the class, while peers are tasked with identifying modifications to the instructions file. Many classroom activities such as this exist for introducing primary literature, and although this has not been assessed directly, the information is provided to stimulate conversation about these activities and provide them as an option for instructors.

2. TOOLS FOR SCIENTIFIC LITERACY

After introduction to the literature process, students must be presented with tools for critical analysis of literature. Scientific literacy related to primary literature may require conceptual and critical thinking skills that are not innately present or require development. Three tools that are helpful for primary literature based learning are JIGSAW, circular response, and C.R.E.A.T.E.

JIGSAW

The jigsaw collaborative learning element is beneficial in a variety of classroom activities including understanding primary literature. In essence, the jigsaw activity allows the instructor to divide the class into groups and assign each group a specific topic (Barkley, 2010). The group is considered the expert on that particular element because they spend the most time working with that topic. Primary literature group activities would consist of having each student read the article presented, followed by dividing the class into small groups and assigning each group to a particular section of the literature paper. The instructor could then reassign the groups, so that each group has an expert from each section of the paper and each person will explain that section in detail to the new group members. The expert groups present their section to the class using an engagement model and visuals for enhanced student understanding (Barkley, 2010). This model integrates an expert group learning situation along with an expert individual among the newly formed groups. These techniques should serve as a reinforcing strategy to improve the comprehension of the primary literature sections, and essentially the paper as a whole.

Primary literature is often difficult for many students to comprehend, so integrating technology might be a way to enhance academic advancement using the jigsaw method (Lai and Wu, 2006). According to Zheng, Lawrence, Warschauer and Lin (2015) an instructor could use Google Docs as a method to engage students in technologically based writing and collaboration in the classroom, which would collectively align with the jigsaw element. If each student in the group is responsible for a portion of the assignment, each group member is able to teach the group about a small section and collaboratively contribute to the presentation through Google Docs. Collaborative learning can be beneficial in understanding difficult assignments because there are a variety of integrative ideas among the group mindset (Ghaith and Bouzeineddine, 2003). The jigsaw methodology provides an interactive technique that instructors can use to improve student understanding by offering an opportunity for peer scaffolding to take place.

Circular Response

According to Janick-Buckner (1997), the majority of undergraduate college students do not have adequate experience reading primary literature, even though medicine and science rely on this information. At first glance, primary literature can be overwhelming and intimidating. It is important to use methods of integration, such as the circular response method, to make primary literature a more comfortable part of a student's skill repertoire. When using this tool, the first step is to let all students introduce themselves and become comfortable with others. Since the whole process is based on discussion, it is important for everyone to be comfortable with expressing their thoughts and questions. Articles are handed out two weeks prior to the beginning of the discussion and students review the article on their own time, then review research background information that might be beneficial to the course (Janick-Buckner, 1997). The first day of discussion consists of talking about why the author chose that research question and relating articles that were similar. One by one, each figure in the article can be examined, while discussing how the experiment was tested, the results, and presentation of the conclusions. Students are asked if they agree with the author's conclusions, or if they can provide alternative explanations. Students discuss how the article and the methods improved their understanding of the topic. The students can then write article reviews individually which helps them express all contributions to the discussion as a group as well as any concerns or questions (Janick-Buckner, 1997). This is a circular process in that students are to come back around with what they gained individually and integrate that with what other class members learned. After expressing their individual ideas, opinions, and takeaways, the group can discuss as a whole what each part of the piece means and how it contributes to the whole purpose of the literature.

C.R.E.A.T.E.

According to Hoskins and Krufka (2015), the traditional methods of teaching used today can lead to misunderstanding of scientific information. It can be difficult for students to recognize and understand the most important scientific concepts. The C.R.E.A.T.E (consider, read, elucidate hypotheses, analyze and interpret data, think of the next experiment) strategy is an engaging and thoughtfully designed toolset that puts students in the driver's seat of their own scientific discovery. Instead of reading out of a text book and memorizing facts for an exam, C.R.E.A.T.E uses primary literature as a gateway into viewing scientific advances and experiments. Journal articles become the center of group discussion, challenging students to create their own ideas, hypotheses, and experiments based on the results they have read. C.R.E.A.T.E is not based on rote memorization. Class time is spent less on feeding students information and more on giving students a real-world experience. There is no right or wrong answer, so students are able to openly discuss any questions or comments with other students or the instructor. Instead of skimming through articles and taking brief notes,

Article Author(s), (publication year)	Outcomes of Using C.R.E.A.T.E. Steps
Hoskins, Stevens, and Nehm (2007)	Students learned how to examine primary literature, interpret data, and analyze results.
Hoskins (2008)	Students worked together to make meaning of results and explain the data to others.
Hoskins and Stevens (2009)	Students discovered the realistic world of research while examining primary literature.
Hoskins (2010a)	Students learned to critically read and analyze data on their own.
Hoskins (2010b)	Instructors showed students who scientists are, what they do, and why they do it.
Hoskins, Lopatto, and Stevens (2011)	Students were more confident with reading, analyzing, and interpreting primary literature.
Gottesman and Hoskins (2013)	Improved students' confidence in primary literature and their ability to form experiments.
Hoskins and Stevens (2014)	Impacted students' attitudes toward primary literature and improved over-all understanding.
Hoskins and Krufka (2015)	Used C.R.E.A.T.E instead of traditional methods to show how experiments are conducted.
Bodnar et al. (2016)	Students had a better understanding of materials and neuroscience primary literature.
Willard and Brasier (2014)	Introducing primary literature early on increases students' confidence in learning.

Table 1. Highlights of C.R.E.A.T.E. steps outcomes.

students are encouraged to make their own concept maps of ideas and questions while reading each section of the literature. This method aids in the decomposition of material so that students can imagine (step-by-step) the experimental process. This encourages students to conceptualize the data as not just numbers, but meaningful information. When examining the data, students are also encouraged to derive their own conclusions before reading the author(s) conclusions. Aside from comprehending information, students are able to see the passion and spirit that goes into scientific experiments. Traditional methods are not very mesmerizing or attractive to students, so the goal of C.R.E.A.T.E is to focus on real-world scientific experience to teach students what scientific discovery is all about (Hoskins and Krufka, 2015).

Hoskins (2010a) has described C.R.E.A.T.E as a multi-step process intended to allow students to focus on primary literature piece by piece instead of trying to gain information for a whole paper all at once. The first step of C.R.E.A.T.E. is called consider, which requires students to draw their own concept maps of ideas, writing down any unfamiliar topics, vocabulary, or questions. Students also utilize this step to form an idea about the nature of the study. The read step encourages students to define those words in which they were not familiar, to create drawings or charts depicting existing studies, and use these illustrative tools to present the data so that they can form a better understanding of what the data represent. Then students elucidate the hypotheses, and compare the original hypotheses to the outcome and results of the study. Students will also define any questions that are being examined in the study. Next, students analyze and interpret data by looking back over all notes, illustrations, charts, and hypotheses to interpret what the data mean and compare it to how they have represented the data. Finally, students will think of the next experiment, brain-storm possible related studies for the future, and then describe the steps of the experiment to other students during the class discussion (Hoskins, 2010a). Some of the highlights of the outcomes for incorporating primary literature tools are summarized in Table 1.

3. HUMANIZING THE LITERATURE

Interactions with Scientists

A neuroscientist's research network can be a powerful tool for humanizing the literature in the classroom and enhancing the accessibility of the primary literature. Schinske et al. (2016) pointed out that textbook content alone rarely presents an authentic connection between the students and studied scientific literature. At times, scientists are seen in a very stereotypical profile, leading students to believe that only some people can be scientists. It is important for students to understand that they can be a part of science early on. By engaging in immersive experiences, students can move past any barriers between themselves and a real scientist. A neuroscientist's research network can be a powerful tool for humanizing the literature in the classroom and enhancing the accessibility of the primary literature. Hoskins and colleagues have emphasized humanizing scientists by requiring students to communicate with authors of articles that were reviewed during the C.R.E.A.T.E. process both asynchronously and in real-time (2007, 2010b). Their first cohort of students emailed questionnaires to paper authors and recorded a video of an interview with one author for subsequent classes to watch (Hoskins et al., 2007). In the same vein, course instructors can use tools such as Skype and Zoom to invite neuroscientists in their network to participate in in-class activities and interviews in real time.

Presumably, instructors will encounter the situation that a scientist outside of their network would be the author of a paper that should be included in the course curriculum. TEDTalks (https://www.ted.com/) are an excellent free resource for viewing scientists discussing their work (Romanelli et al., 2014). Although not restricted to neuroscience, members of our neuroscience community whose work is deeply embedded into our curriculum have contributed videos to the TED repertoire including, but not limited to: Drs. Vilayanur Ramachandran, Christopher deCharms, Jill Bolte Taylor, and Oliver Sacks.

Immersive Experiences

Field trips to department or university colloquia, university seminars, or conferences can be embedded into neuroscience curriculum as often as possible. These activities are the cornerstone of the development of a research network which can benefit transition into graduate school. Sometimes, we may be able to share rare immersive experiences based on colloquium speaker timing. For example, students at Tarleton State University were able to travel to a nearby university (University of Texas at Arlington) during the speaker series that included a lecture by Dr. Jane Goodall. Her talk was a remarkable opportunity for our Animal Behavior students that had been learning about neural mechanisms of behavior. Knowing about her involvement in the lecture series in advance gave us the opportunity to incorporate her published work into the class curriculum, and cap off the class with a trip to her lecture.

Study abroad is a wonderful immersive learning experience that unfortunately many students will not have. Ultimately, instructors that participate in these activities can share the experience with students in future non-study abroad classes by creating PowerPoints and videos depicting their experiences in the field abroad. Students who have had the opportunity to participate in study abroad programs have reported that the immersive experience has helped them to gain a sense of cultural diversity, intercultural communication skills, and has caused them to become more open minded than students who remain in the traditional classroom setting (Clarke et al., 2009). Immersive experiences may help spark student interest and can facilitate development of a global perspective (Brewer and Cunningham, 2009).

CONCLUSION

Graduates are expected to be familiar with the literature in their field. It is the responsibility of educators and students together to ensure that students are sufficiently prepared by the time they graduate to utilize and contribute to the literature in their field. Preparation is key when it comes to graduating college, going to graduate school, or finding a career, so it is intuitive to enable college students to further their own opinions and knowledge about real-world scientific discoveries. This review describes multiple tools that can facilitate literacy related to primary literature in the undergraduate classroom as a resource for instructors. Key components of the review are summarized in Figure 1 to facilitate implementation.

We reviewed methods for integrating primary literature into the classroom and separated them into three components including: (1) introduction to the literature, (2) enhancement of literacy and comprehension, (3) and humanizing the literature.

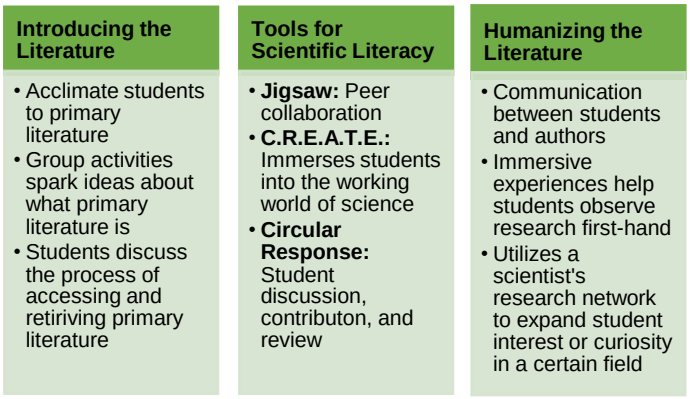

Figure 1. Available tools for integrating primary literature.

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