Teaching the Anatomy of a Scientific Journal Article

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Three activities engage students in the process of science

Jeffrey N. Schinske, Karen Clayman, Allison K. Busch, and Kimberly D. Tanner

An overarching goal of inquiry-based science education is to have every student experience the world as a scientist: wondering, asking questions, doing experiments, defending their ideas, and communicating their work (NRC 1996). To promote inquiry-based learning, we integrate the anatomy of a scientific journal article into our secondary science curriculum.

In this article, we present three classroom activities used to teach students about the function and format of scientific journal articles. The first focuses on journal article figures, the second on journal abstracts, and in the third, students produce their own journal articles on inquiry-based investigations they have conducted. We also present data on student attitudes, which indicates that students exhibit a high level of confidence in their scientific reading and writing skills as a result of these activities.

Introduction

In terms of communicating scientific work, one of the most exciting times in any scientist's career is the first time his or her work is published and made available to the public. Seeing one's own scientific writing bound for others to view is a significant accomplishment, and most scientists feel fortunate if they experience this for the first time as an undergraduate or graduate student. However, we feel this experience could occur much earlier in a budding scientist's career and could serve to engage all students—future scientists or otherwise—in the process of science.

While students in our classes have created posters and made short group presentations in other science classes, we find that authentic scientific writing is less prevalent. At the college level, science educators often introduce primary literature and scientific reports to their students (Janick-Buckner 1997; Miller 1978), but it is less common to implement this at the secondary level (Yarden, Brill, and Yarden 2004). Given the journal articles to the process to incorporate authentic scientific articles to support inquiry-based science is created by working class publication to formal science writing.
To guide our students in gaining familiarity with the format of scientific journal articles—shown by example in this article—we developed three classroom activities. It is important to note that these activities do not require students to read articles from the primary literature, but focus instead on the more general form and function of scientific articles. These activities—designed to meet National Science Education Standards (NRC 1996) that require instruction in scientific inquiry and the process of science—address Content Standard A (Science as Inquiry), in that students will

- identify questions and concepts that guide scientific investigations (p. 175), and
- communicate and defend a scientific argument (p. 176).

We hypothesized that the activities designed would engage our students in science inquiry, give them a sense of pride in their abilities as scientists, and bolster their confidence for future scientific work.

**Methods and materials**

**Classroom activities**

We developed three key classroom activities to teach students about scientific journal articles, which we conducted during the 2005–2006 and 2006–2007 school years. Each is facilitated during separate back-to-back 50-minute periods. The first, “Article Figure Analysis,” focuses on the ways graphs, pictures, and diagrams contribute to scientific communication. The second, “Analysis of a Scientific Abstract,” illustrates how the personal interests and hobbies of scientists impact their studies by inspiring wonder. The third activity, “Independent Journal Article Composition,” involves students producing independent written reports in the form of authentic journal articles, which are based on their own inquiry-based investigations. This final activity takes place over a few weeks as students work on their articles at home and submit drafts prior to classwide publication.

All of the journal articles used in class are obtained using the Google Scholar free search engine (see “On the web” at the end of this article). When possible, we incorporate articles that relate either directly to course content goals or generally to popular culture. For example, searching for “basketball free throw” on Google Scholar returns numerous articles on the interplay between physics, psychology, visual ability, and the free throw. For the majority of the classroom activities described, full-text versions of published articles are not needed. However, complete versions of all the articles are readily available through public libraries or universities if desired, and electronic copies can often be quickly obtained through these sources. (Note: Teachers who want their students to read complete articles can visit www.nsta.org/highschool/connections.aspx for these resources.)

In all activities, we use specific strategies to minimize potential learning barriers that could arise from vocabulary or reading issues. We emphasize that it is acceptable not to know the meaning of every word in scientific writing. Scientists often do not understand the specific jargon from fields outside their own, yet they can use context and diagrams to gain a general understanding of other scientists’ work—and our students are encouraged to do the same.

Early in the school year, we introduce the concept of a scientific journal article to our students through a group discussion. We ask students what they know about journal articles and show them an example on an overhead projector. The content of the article is not important at this point, since the goals are to

- discuss how scientists use journal articles to communicate, and
- demonstrate the order and importance of traditional journal article sections: title, authors, abstract, introduction, materials and methods, results, discussion, and figures.

We talk about the importance of each of these journal sections and discuss how the format can provide an efficient way for scientists to exchange ideas. (Note: For brief descriptions of each of the journal sections, visit www.nsta.org/highschool/connections.aspx.) We emphasize that presenting information in a consistent way in journal articles makes it easy for scientists to find relevant information. Introducing the basic vocabulary regarding the anatomy of a scientific journal article allows us to refer back to those words when discussing different components of laboratory activities that we perform during the year. In our lab worksheets throughout the year, we organize the information into journal article sections and refer to students’ laboratory observations, conclusions, and drawings by the journal sections they correspond to.

**Article Figure Analysis**

The first formal journal article activity we perform with students is the Article Figure Analysis. This activity is sometimes used in undergraduate or graduate education, and involves analyzing, marking up, and presenting a figure (e.g., drawing, picture, or graph) from a journal article (Figure 1).

The objectives of this activity are to

- examine the role of figures in scientific journal articles,
- use the visual media within articles to help students gain access to the article format, and
- connect course content to ongoing scientific research.
Original caption for figure.

"Quasi-static stress changes are one mechanism that might connect eruptions to earthquakes. (a) As the Juan de Fuca and North American plates converge, strains gradually accumulate along the Cascadia subduction zone. The accumulated strains are released every few hundred years by the abrupt thrusting of the oceanic plate beneath the overriding continental plate to produce a magnitude-9 "megathrust" earthquake. Following the megathrust earthquake, changes in stress quasi-statically diffuse inland toward nearby volcanoes. Background earthquake activity (small dots) occurs during the interval between megathrust earthquakes. (b) The composite annual eruption rate of Cascades volcanoes [smoothed using a uniform moving window] shows a marked increase following the magnitude-9 earthquake on the Cascadia subduction zone in 1700. The red curve shows calculations of the volumetric strain below the Cascade volcanoes that followed the earthquake. The peak strain precedes the peak eruption rate by about 50 years" (Hill, Pollitz, and Newhall 2002).

Figure caption translated by teacher.

The upper figure shows the locations of some volcanoes along the west coast of the United States. In the year 1700, there was a huge, 9.0 earthquake along the Cascadia subduction zone. To see if this earthquake was related to volcanoes, we plotted the number of volcanic eruptions in the lower figure. In this graph, the number of eruptions per year is plotted for the years 1200–2000. The black, vertical line shows when the 9.0 earthquake hit. About a hundred years after the earthquake, there was a large peak in the number of volcanic eruptions. We think that the earthquake caused high stress in the magma below the volcanoes, which made them erupt many times following the earthquake. The curve on the graph starting at the black line shows our prediction of the amount of stress on the volcanoes after the earthquake. We think the amount of volcanic stress peaked just before the major eruptions started.

Reprinted with permission from Hill, Pollitz, and Newhall 2002.
To conduct this activity, teachers should follow these procedures:
- Select a figure-rich journal article relating to course content (we selected an earthquake-volcano article for our Earth science class).
- Translate figure captions to more accessible language for students.
- Place students in groups of four and give each a figure with a caption on an overhead transparency.
- Instruct students to review the figure and make at least six notes directly on the transparency to help describe their figure.
- Have student groups present their figures to classmates using an overhead projector.

See Figure 1A (p. 51) for an original journal figure and caption and Figure 1B for a sample figure analysis completed by a student and a teacher-translated caption.

**Analysis of an Abstract**
We perform this second journal article activity at the same time that our science fair-project assignment is introduced. At this point, we work on cultivating students’ wonder about their world so they can brainstorm ideas for their own science projects.

The objectives of this activity are to
- demonstrate the utility of an abstract in scientific writing,
- use actual scientific article abstracts to demonstrate the ways scientists wonder about the world, and
- cultivate students’ wonder about the world to assist in their development of science fair projects.

To conduct this activity, teachers should follow these procedures:
- Select many journal article abstracts relating to subjects of common interest, including food, video games, and sports (see Figure 2 for examples).

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**FIGURE 2**

**Sample journal article abstracts.**

<table>
<thead>
<tr>
<th>Title</th>
<th>Topic</th>
<th>Citation</th>
</tr>
</thead>
</table>
Articles could additionally include topics and authors drawn from a wide range of cultural and ethnic backgrounds.

- Print only title, author, and abstract portions of articles selected.
- Provide pre-assessment to probe students' ability to recognize their own wonder about world.
- Distribute abstracts to student groups, prompting them to try to infer what the authors' personal interests or hobbies might be (i.e., what made them wonder about that subject).
- Facilitate classroom discussions in which small groups present their abstracts and their inferences about the authors' wonder.
- Provide postassessment (the same as pre-assessment) to see if students' ideas of wonderment have changed.

**Independent Journal Article Composition**

At the conclusion of the science fair, students begin the process of composing their own scientific articles based on their projects. We remind students of the numerous journal article sections they have seen throughout the year so far, and discuss what students have noticed about abstracts, figures, and the other sections scientists use. We explain that this is an opportunity for students to bring together all that knowledge to organize their individual experiment ideas into their own, authentic scientific articles. Students' articles are meant to be brief, while still including all the main journal article sections and at least one figure. While our students' articles were based specifically on science fair projects, this article-writing activity could follow any science project or inquiry-based lab.

The objectives of this activity are to

- provide a formal opportunity for students to demonstrate their understanding of the anatomy of scientific journal articles, and
- create a bound in-class publication to recognize student achievement in doing and writing “real science.”

To conduct this activity, teachers should follow these procedures:

- Facilitate student presentations of completed science fair projects to the class.
- Have classmates provide verbal feedback to the student presenters.
- Hand out the Journal Article Composition Assignment Sheet. (Note: This sheet is available online at www.nsta.org/highschool/connections.aspx.)
- Instruct each student to prepare a draft article about his or her project.
- Provide written feedback to students on their draft journal articles.
- Collect and bind final drafts of student articles.

**FIGURE 3**

End-of-year survey.

Open response (retrospective postassessment)

1. Before this year's science class, I thought scientific papers were...

2. Now I think scientific papers are...

<table>
<thead>
<tr>
<th>Statement (Likert questions)</th>
<th>Agree</th>
<th>Agree a little bit</th>
<th>Not sure</th>
<th>Disagree a little bit</th>
<th>Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>3. The Article Figure Analysis, Analysis of a Scientific Abstract, and Journal Article Composition are different from what I have done in my previous science classes.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>4. I think I could describe to another person the ways scientists present and publish the results of their research.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>5. If someone showed me a real scientific research article from a journal, I think I could figure out the question the scientists asked, what they did, and what their main conclusion was.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>6. I consider myself a science person.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

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**Figure 4**

Sample student responses to retrospective postassessment.

<table>
<thead>
<tr>
<th>Attitude change?</th>
<th>Before this year's science class, I thought that scientific papers were...</th>
<th>Now I think scientific papers are...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive</td>
<td>&quot;going to be hard and confusing.&quot;</td>
<td>&quot;clear and sometimes fun to do.&quot;</td>
</tr>
<tr>
<td>Positive</td>
<td>&quot;confusing and boring. There were a lot of variables, which I did not get.&quot;</td>
<td>&quot;summaries of my science project and are important to have.&quot;</td>
</tr>
<tr>
<td>Positive</td>
<td>&quot;going to be really hard and not interactive.&quot;</td>
<td>&quot;fun, challenging, not hard, and interactive.&quot;</td>
</tr>
<tr>
<td>Positive</td>
<td>&quot;notes and what happens to the project.&quot;</td>
<td>&quot;qualitative and quantitative observations, inferences, hypothesis, procedures, conclusions, materials, etc.&quot;</td>
</tr>
<tr>
<td>Positive</td>
<td>&quot;just papers about science or scientific writing.&quot;</td>
<td>&quot;what scientists write so that other people can learn from them. They have facts, results, and figures.&quot;</td>
</tr>
<tr>
<td>None</td>
<td>&quot;papers that explain a project.&quot;</td>
<td>&quot;papers that explain their project/solution.&quot;</td>
</tr>
<tr>
<td>Negative</td>
<td>&quot;boring unless topic is interesting.&quot;</td>
<td>&quot;even more boring.&quot;</td>
</tr>
</tbody>
</table>

with cover pages and a table of contents.

- Distribute bound journals to students and place copies in the school library.

**Measuring impact**

We assess progress toward our learning goals in these activities through observations of group presentations, pre- and postassessment of the abstract reading activity, grading of student articles, and an anonymous survey of student attitudes at the end of the year. This end-of-year survey includes a retrospective postassessment (open response) section and a Likert scale (statement) section (Figure 3, p. 53). We analyze the retrospective postassessment data by looking for indications that student attitudes regarding scientific papers have changed from negative or uninformed to positive or more sophisticated from the first statement to the second. Likert scale data is analyzed by examining the distributions of responses to the statements.

The following sections present the results of conducting these journal article activities in our classroom during the 2006–2007 school year.

**Results**

**Student engagement and success**

We found secondary science students to be very engaged in examining scientific journal articles. In each exercise, every student group successfully navigated the tasks and completed the assignments. While observing students during activities, we found them to be on-task and dedicated to the difficult objectives presented to them. Students pushed through any initial confusion as a result of their desire to grasp authentic scientific materials. The authenticity of the activities and their direct relation to science inquiry appeared to be highly motivating for students.

In the Article Figure Analysis, students showed a great deal of enthusiasm in working with overhead transparencies and marking up their own color figure (Figure 1, p. 51). By presenting this figure to the class, students gained an appreciation for the role of figures in journal articles, advanced their understanding of a course content goal (i.e., earthquake-volcano interactions), and practiced oral-communication skills in science.

All student groups also successfully completed the Analysis of a Scientific Abstract, though many groups needed guidance to work through the vocabulary. Students were surprised to learn that real scientists performed research on subjects such as basketball, cooking, and video games (Figure 2, p. 52). This showed students how formal scientific research and writing can relate directly to their daily lives.

In the Independent Journal Article Composition, students' scientific journal articles varied in length and level of sophistication, but all students displayed in their writing a general understanding of the basic format and function of scientific articles. We noticed that
**FIGURE 5**

**Student responses to Likert questions.**

These histograms show distributions of student Likert scale responses to Statements 3, 4, 5, and 6 on the anonymous end-of-school-year survey in Figure 3 (p. 53). *(Note: 1 = Agree, 2 = Agree a little bit, 3 = Not sure, 4 = Disagree a little bit, and 5 = Disagree)*

A. **Activities Different from Previous Science Classes**

Statement 3

B. **Could Describe How Scientists Present/Publish Work**

Statement 4

C. **Could ID Information in a Real Journal Article**

Statement 5

D. **Consider Myself a Science Person**

Statement 6

many students used the comments of their peers from in-class presentations to improve the ways they communicated about their projects.

At the end of the year, we reserved one class session to ceremonially distribute students’ copies of the class publication. We individually named the students and their project titles as they received their copy and celebrated students’ accomplishments. We have now produced classroom journal article compilations for the 2005–2006 and 2006–2007 years. These journals are available for public viewing by request via e-mail from the Science Education Partnership and Assessment Laboratory Resource Center (e-mail: sepal@sfu.edu).

**Student beliefs and attitudes**

To assess our hypothesis that the activities we designed would engage our students in science inquiry, give them a sense of pride in their abilities as scientists, and bolster their confidence for future scientific work, we collect and analyze end-of-year survey data.

On the day of the survey in 2007, 61 students were present in our two Earth science classes, and that number represents our sample size for the survey dataset. The retrospective postassessment revealed that 40 out of 61 students claimed to have a more positive or more sophisticated view of scientific articles at the end of the year.
compared to their views at the beginning (see Figure 3, Open Responses 1–2, p. 53). Only one student claimed to have a more negative view of scientific articles after the activities. The remaining 20 students did not describe their attitudes about scientific articles as significantly different compared to the start of the year. Figure 4 (p. 54) shows examples of student responses to the retrospective postassessment.

The distributions of Likert scale responses to the other survey statements (see Figure 3, Statements 3–6, p. 53) are shown in Figure 5 (p. 55). Perhaps most striking are student responses to Statements 3 and 5 (Figure 5, Graphs A and C). The vast majority of students (53) agreed that the three journal article activities described in this article were “different from what [they have] done in [their] previous science classes.” The average class response was 1.6 with only four students circling 4 or 5 (disagree). Even more striking were the responses to the statement, “If someone showed me a real scientific research article from a journal, I think I could figure out the question the scientists asked, what they did, and what their main conclusion was.” No students disagreed with this statement (circled 4 or 5). The average class response was 1.95 with 47 of 61 students agreeing (choosing 1 or 2).

Discussion

Student responses indicate significant progress toward our goals for the activities. In their written responses from the end of the year, most students display a relatively sophisticated understanding and positive view of scientific writing. Most surprising is the finding that none of the 61 students disagreed that they would be able to identify the scientific questions, procedures, and conclusions in a real journal article. The level of confidence students seem to have in their ability to navigate complex scientific material in journal articles is quite striking.

The main obstacle to working with journal articles in secondary science classrooms seems to relate to language difficulties inherent in some scientific writing. However, it is important to reiterate that our activities do not involve assigning entire journal articles to students to read. We focus instead on the more accessible anatomy of journal articles, allowing us to take a more general view of their structure and function. Translating the captions proved useful in the Article Figure Analysis activity, so we might also translate elements of the abstracts to bypass language barriers in future classes.

Importantly, these activities require relatively few resources and materials. An internet connection, paper, and overhead transparencies are the only resources needed to prepare for most of them. Binding the journal articles for our two classes costs under $200 at a local copy services store, but this can been done less formally using in-house binding machines and supplies. In addition, we find that many of our colleagues ask for copies of our journals as a resource for their students. These teachers wish to show their students examples of science fair projects that can be built upon or enhanced. This makes our class publications a potentially valuable resource in other classrooms, as well as our own.

Overall, we feel that introducing the anatomy of journal articles in secondary science classrooms is an engaging way to promote inquiry-based learning. We are encouraged by the fact that students gain confidence in their own scientific abilities as a result of these activities and hopeful that this confidence will promote students’ success in future science classes.

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On the web

Google Scholar Search: http://scholar.google.com

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