Undergraduate introductory biology students struggle when communicating quantitative data. This activity provides students with a real-world research experience to improve their quantitative literacy in science communication. Students were provided with a national sports media report that described a professional football athlete requiring 9,000 calories daily. Students were then asked to determine whether, based on their own research and calculations, the reporter had correctly calculated the total calories coming from the reported foods. Students discovered that their different sources of caloric information provided very different (albeit accurate) calculated totals, ranging from 6,000 to 11,000 calories. Importantly, the students generated professional letters outlining their calculated differences and sent them to the sports reporter. The professional letters to the reporter were assessed via rubric for accuracy of calculations, appropriate research evidence, professionalism, and readability for a nonexpert. A majority of the students provided accurate calculations; however, students scored lower on their professional writing skills, ability to cite appropriate research evidence, and readability for a nonexpert. Additionally, summative quantitative problems were individually completed and assessed, and activity cohorts achieved significantly higher on these problems compared with the non-activity cohort. Finally, surveyed students indicated that the activity helped prepare them for quantitative problems on the summative exam and helped them identify major course learning objectives. In conclusion, given an authentic research activity, students can take ownership of their learning and practice their communication to the general public about quantitative scientific information.

INTRODUCTION

The scientific communication of quantitative information is part of the major core competencies for biology majors (1). For these students, as well as for nonscience majors, there are few coursework activities that provide practical, engaging experiences in communicating their scientific knowledge to nonexperts (2). While many institutions are implementing science communication skills into their curricula, students are often not being asked to write to nonexperts, but to fellow students or faculty (3, 4). Currently, there are national calls for additional training opportunities for science students to gain science communication skills (5). Additionally, many efforts and programs already underway seek to enhance scientists’ communication to nonexperts and bridge the science–public divide (4, 6). Finally, there are guides available to help scientists communicate with lay audiences and nonexperts (7); however, most undergraduate students are not willing to assign themselves additional tasks beyond their course requirements to achieve quantitative literacy, that is, proficiency in understanding, interpreting, and communicating numerical information. It is hard enough for students to communicate science effectively; it is harder still when the science that they are trying to communicate is quantitative in nature (8). Therefore, there is a need for activities geared to real-world application and engagement that help our undergraduate students refine their quantitative scientific communication skills (9, 10). This activity was developed for students to practice their communication of complex, quantitative information with nonexperts, while maintaining students’ active interest in the process.

This activity was designed to engage introductory nutrition students in a problem presented in the form of a national sports report about the caloric intake of a popular football athlete. The activity was designed for a broad audience with few skills in quantitative scientific communication. Additionally, while each year’s cohort consisted of students at different levels of education, most of the students each year were freshmen.

The primary learning outcomes were for students to be able to:

1. Research and calculate caloric information from food sources presented in a sports report
2. Write a professional letter to a sports reporter comparing their own data analysis with the content of the sports report
3. Accurately complete quantitative problems on summative assessments

PROCEDURE

Students were provided with a brief sports report (in either video or print form) outlining a professional football athlete’s daily requirement of 9,000 calories to maintain their high-performance sports physique. The report stated that in order for the athlete to gain 9,000 calories, they would need to consume a shocking 50 slices of bacon, 20 chicken breasts, and 13 avocados. Students were asked to research these food items and determine from the stated food whether or not these quantities would equal 9,000 calories. Students worked in small groups (3 to 4 participants per group) during a single 50-minute class period and used various online sources to determine the quantity of energy derived from the food sources. Students used their knowledge of energy conversions presented during an earlier class session. Groups continued their research for two days outside of class and then submitted their calculations online. Data were collected by the instructor from all groups and then reported back to the entire class during the following session.

During the presentation of class data, it is important for the instructor to explain the reasons why every group obtained a different calculated result. (It should be noted that the results of the calculations varied from 6,000 to 11,000 calories, and no two groups across three consecutive years had identical final values.) This is an excellent time to talk about sources of information and how the source can greatly influence data and interpretation. For example, different cuts or subtypes of bacon provide different quantities of calories.

Groups were then given a week outside of class time to write professional letters to the sports reporter about their conflicting calculations. Examples of student work are provided in Appendix 1. Knowing that a sports reporter would be sent their work after their submission may have provided added motivation for the students.

IMPLEMENTATION

To successfully implement this activity, an instructor needs access to a sports report about an athlete’s caloric consumption. A quick search online for “9,000 calories football” and “calories of professional athletes” will reveal several options, including the one used for this activity. Students really enjoy access to a video report, but an article will suffice. This activity works well if the students work in groups and assign a food source to each member, providing tasks for all during the activity. Additionally, in-class research time allows instructors to formatively check to see that all group members have an equitable experience. Also, students could be asked to perform a group self-evaluation of their final written letter so the instructor is aware of the students’ perceptions of the expectations within the activity. Importantly, for growth of students’ science communication skills, students may be asked to revise their professional letters after a session with an institution-sponsored writing tutor. It benefits students to have writing tutoring as a required part of the formative assessment.

CONCLUSION

Students’ individual quantitative literacy skills were evaluated through summative assessment exam questions for four consecutive years (2014 to 2017). Students in the control cohort (2014) were provided with traditional in-class and homework-style quantitative energy conversion problems to practice their quantitative analysis skills. Students in the activity cohorts (2015 to 2017) were provided with the activity described here as their practice. All students were given the summative assessment as part of the course testing over the same learning outcomes. All individual student data scores were analyzed from all cohorts. Students in the activity cohorts achieved significantly higher on their summative energy-conversion problems when compared with students in the non-activity control cohort as analyzed by a two-sided student’s t-test ($p = 0.003$) (Fig. 1A). This improvement was
exciting because the same students performed equally ($p = 0.56$) on the overall nutrition summative assessment, which assessed other course learning outcomes (Fig. 1B). Thus, improvements in learning were made through this activity specifically regarding quantitative analysis. Detailed annual cohort breakdown and examples of summative assessment questions are presented in Appendix 2.

Important, student groups in the activity cohorts were assessed for quantitative literacy and scientific communication skills via their professional letters to the reporter. The rubric, which assessed accuracy of calculations, appropriate research evidence, professionalism, and readability for a nonexpert, is provided in Appendix 1. Bin analysis was performed on these categories using a four-point grading rubric (Table 1). Students scored highest in calculating quantitative data, with 78% scoring proficient or higher. Excitingly, this data is predictive of a student's individual success at accurately completing quantitative problems, as seen in the summative assessment. Somewhat lower results were seen for their ability to write to a nonexpert, with 72% reaching a score of proficient or higher. Students' major struggle in writing to a nonexpert was largely due to the frequent use of scientific jargon seen in many letters. This could be due to the fact that the students are nonexperts and maybe did not understand the jargon themselves. Thirdly, students' abilities to effectively support their work with appropriate scientific evidence was lower, with 67% attaining a proficient or higher score. This low percentage could perhaps be attributed to general novice knowledge of citing work in a letter, as a majority of the cohorts were co-enrolled in their first college-level writing course while taking this class. Finally, students individually evaluated the perceived impact of the activity via feedback through Likert-type scale (5-point) survey questions given after the summative assessment. Activity participants were invited to participate in this optional survey. These data indicate that 83% of the respondents ($n = 46$) agreed or strongly agreed that the activity helped them prepare for the summative assessment problems and helped them identify the major course learning outcomes. Additionally, no students in the three activity cohorts indicated disagreement with these statements, and the remaining 17% neither agreed nor disagreed with these perceived impacts. Individual students' positive comments reinforced these survey results and are provided in Appendix 3 along with survey questions and a figure summarizing the full survey analysis.

Overall, engaging the learner in quantitative literacy is complicated by many undergraduates' preconceived discomfort with quantitative data. Their engagement can quickly be enhanced by experiences that speak to them and have realistic application. This activity engages students in quantitative literacy and allows them to communicate quantitative information to nonexperts. This is seen as a major skill that students must obtain to be successful in their careers.

### TABLE 1
Analysis of rubric-graded criteria for professional letter assessment.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Level of Performance</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Distinguished</td>
</tr>
<tr>
<td>Accuracy of calculations</td>
<td>50%</td>
</tr>
<tr>
<td>Appropriate research evidence</td>
<td>45%</td>
</tr>
<tr>
<td>Professionalism</td>
<td>33%</td>
</tr>
<tr>
<td>Readability for a nonexpert</td>
<td>22%</td>
</tr>
</tbody>
</table>

Percentages describe the fraction of groups that met the rubric requirements for a specific level of performance.
SUPPLEMENTAL MATERIALS

Appendix 1: Rubric used to evaluate scientific letters to a nonexpert, analysis of rubric-graded criteria for professional letter assessment for 2017 cohort (first submission and second submission after writing tutoring session), and examples of student work.

Appendix 2: Cohort summative exam performance and examples of summative assessment questions.

Appendix 3: Survey questions and analysis, and student responses.

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REFERENCES