A QUARTER-LONG EXERCISE THAT INTRODUCES GENERAL EDUCATION STUDENTS TO NEUROPHYSIOLOGY AND SCIENTIFIC WRITING

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Providing large numbers of general education students with an introduction to science is a challenge. To meet this challenge, a quarter-long neurophysiology project was developed for use in an introductory biology course. The primary goals of this multistep project were to introduce students to the scientific method, scientific writing, on-line scientific bibliographic databases, and the scientific literature, while improving their academic literacy skills. Students began by collecting data on their own circadian rhythms in autonomic, motor, and cognitive function, reliably demonstrating the predicted circadian changes in heart rate, eye-hand coordination, and adding speed. Students wrote a journal-style article using pooled class data. Students were prepared to write the paper by several methods that were designed to improve academic language skills, including a library training exercise, "modeling" of the writing assignment, and drafting of subsections of the paper. This multistep neurophysiology project represents a significant commitment of time by both students and instructors, but produces a valuable finished product and ideally gives introductory students a positive first experience with science.

Key words: second language students; circadian rhythms laboratory exercise; neuroscience laboratory exercise; scientific method; scientific bibliographic databases

Providing large numbers of introductory level, general education students, who may have little or no previous exposure to science, with an appropriate and relatively inexpensive introduction to the process of scientific investigation is a challenge. When the majority of these students are high-risk, language minority students (i.e., immigrant or native-speaking English bilinguals) and are the first in their families to attend university, this challenge is augmented significantly. To meet this challenge, a quarter-long neurophysiology project was developed for use in a general education introductory biology laboratory course. The experiment itself was a relatively simple exercise on circadian rhythms modified from Montgomery and Elliot (6), whereas the writing and library components were constructed de novo for this project. Throughout development of this project, emphasis was placed on both academic content and methods to improve academic language skills of the students.

This multistep neurophysiology project was first piloted in winter quarter 1994 and has been modified during four subsequent academic terms. The project was originally piloted when funds were available so that the course could be taught with an adjunct study group (winter quarter 1994, 89 students). In succeed-
Innovations and Ideas

In training terms, the exercise was revised and was successfully used without the adjunct study group (winter and spring 1995, winter and summer 1996; 122, 144, 181, and 106 students, respectively). Consequently, many of the study group exercises described in this paper are not currently in use in the course. However, if adequate in-class time is available, they can easily be modified for incorporation into normal class sessions. The primary goals of this multistep project are to introduce general education students to 1) the scientific method, 2) scientific writing, 3) on-line scientific bibliographic databases, and 4) the scientific literature, while improving their academic literacy skills.

PROCEDURE

Equipment

One great advantage of this exercise is that it requires little equipment and so is extremely low cost, even for large classes. The only equipment needed is the number table provided in the laboratory handout (4) and a watch or clock with a second hand.

Protocol

Experiment. The circadian rhythms project began during the second week of the quarter. The students received a short lecture, based on the laboratory handout (4), that introduced them to biological rhythms. They then collected their first set of data on their own circadian rhythms in autonomic (heart rate), motor (eye-hand coordination), and cognitive (adding speed) function. The laboratory handout provided specific instructions for the collection of data during both the normal rest and activity periods, which were reviewed briefly by the course instructor. This portion of the experiment required ~1 h of the second week laboratory session.

The students had 1 wk to collect data for their remaining circadian time points (i.e., 12 time points total, spaced at 2-h intervals; see Ref. 4). Students were encouraged to spread their data collection over the full week so that the exercise was not unreasonably disruptive to their normal sleep-wake schedule. In addition, students were not penalized for missing data points, unless no attempt had been made to collect data. Students entered their data in the table provided in the laboratory handout, which also contained a space to indicate the normal awakening and bedtimes. The data tables were submitted to the course instructor during the week 3 laboratory session.

The course instructors summarized the data for their laboratory section and distributed these data to the students during the week 4 class session. The laboratory sections enrolled 15-26 students, which provided a reasonable sample size for the experiment. Data from individuals whose awakening or bedtimes were ±2 h different from the class mean were not included in the summary data set. The summary data were provided as raw numbers in tabular form. Thus each student calculated sums and means for each variable at each circadian time point to plot the data for use in his or her paper. This procedure ensured that students received some experience with simple statistics and the variability inherent when making physiological measurements of populations.

Library exercise. Students were also introduced to the library research process during the week 2 laboratory period. The course instructor gave a general tour of the library in which they explained a variety of basic concepts, such as how to find books and journals. The students then received hands-on training in the available bibliographic databases and were asked to complete an exercise demonstrating basic proficiency in using these resources (4). This exercise required ~1.5 h of in-class time. Most students completed the exercise within this time period. However, students were given 1 wk to submit the assignment, which allowed them to spend extra time exploring the available bibliographic databases or developing basic computer skills. The basic library research skills introduced in this exercise were essential to the successful completion of their writing assignment because they were required to support/explain their experimental findings with published research findings.

Writing assignment. The writing of the scientific paper was a multistep process that began with a general introduction to the assignment. Approximately 30 min of the week 2 laboratory period was devoted to a general introduction to the different sections found in a scientific paper and to the stepwise process that would be used to produce the final version of the writing assignment. The information
TABLE 1

Multistep process used in writing the scientific paper

| Week 2 | A. Begin collection of personal chronobiology data  
B. Exercise, "Introduction to the library research process"  
C. Lecture, "General introduction to writing a scientific paper" |
|--------|--------------------------------------------------|
| Week 3 | A. Personal chronobiology data due  
B. Lecture, "Introduction to a good materials and methods section" |
| Week 4 | A. Pick up class data set that has been compiled by instructor  
B. Drafts of materials and methods section due  
C. Lecture, "Introduction to a good results section" |
| Week 5 | A. Pick up drafts of materials and methods section with comments  
B. Drafts of results section due  
C. Lecture, "Introduction to a good introduction section" |
| Week 6 | A. Pick up drafts of results section with comments  
B. Drafts of introduction section due  
C. Lecture, "Introduction to good discussion and literature cited sections" |
| Week 7 | A. Pick up drafts of introduction section with comments  
B. Drafts of discussion and literature cited section due |
| Week 8 | Pick up drafts of discussion and literature cited sections with comments |
| Week 10 | Final, revised version of complete scientific paper due |

Drafting of the assignment occurred during weeks 3-8, with the final paper due during the tenth week of the quarter (Table 1). Students had 1 wk after the discussion of a specific section of the scientific paper to produce a draft of that section and submit it to the laboratory instructor for comment. One drawback to this process was that, during weeks 4-7, students had writing assignments due on a weekly basis; however, each individual assignment was relatively short and the process appeared to be manageable for the majority of the students. The laboratory instructor critiqued the drafts and returned them, with detailed comments for improvement, within 1 wk of submission. The final revised version of the paper, containing introduction, materials and methods, results, discussion, and literature cited sections, was due during week 10.

Study group exercises. The study group exercises described in this section were embedded within an adjunct study group course taught in the winter quarter of 1994. The adjunct study group course met twice a week for a total of 4 h per week, and the activities corresponding to the writing assignment were taught by a language specialist. The activities designed for this adjunct course were directly related to the weekly writing requirements in the linked lecture/laboratory course. For example, in weeks 3 and 6, the study group activities were designed to teach students how to write the materials and methods, the discussion, and the literature cited sections, respectively (Table 1).

Instruction in the study group contained two features that contributed to the students' awareness of the requirements of the scientific paper: 1) modeling through authentic scientific writing samples and 2) reflecting on their own and other students' performance. Much like in the laboratory class linked to the study group course, modeling in the study group involved providing students with student-produced samples of single sections of the scientific paper and making students aware of the samples' rhetorical and linguistic demands. The samples used in the study group course differed from the ones used in the laboratory class both in terms of content and in the lexical choices made by the student writers. These differences helped promote the idea that, far from being a formulaic task, scientific writing allowed for differences.

Modeling of the assignment occurred during weeks 3-6 (Table 1). Approximately 20 min was used during these laboratory meetings for a detailed discussion of a single section of the scientific paper. These discussions made use of a "model" student paper that had been written by a senior biology student for an upper division course. Overhead transparencies were made that indicated how this paper fulfilled the criteria given in the laboratory manual for writing the different sections of a scientific paper. In addition, there were comments about how the paper could be improved. A student-generated "model" paper, rather than a paper written by a faculty member, was used so that the students could see how an advanced peer responded to a similar assignment.

covered in this presentation was also found in the laboratory manual (4).

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The models used in the study group included samples of well-written and poorly written sections. Well-written samples provided the students with information on strategies that successful writers used to complete the scientific assignment. The poorly written samples gave students a valuable opportunity to determine which conventions of scientific writing had been omitted and allowed the students to decide how those omissions could be corrected.

Reflecting on their own and on other students' performance involved the students' analyzing the models provided as well as their own and other students' drafts through a process of guided and independent practice (8). The process of reflection began with the students using a checklist (Table 2) to analyze the well-written and poorly written samples and to decide whether revisions were in order. As a follow-up homework assignment, students completed the first draft of a single section. In class, students were asked to work in pairs, read their peers' drafts, and, using the checklist, provide one another feedback. The next step consisted of having the students revise their drafts and self-assess the revised sections using the same checklist. As a final step in the reflection process, students were given a handout entitled "Evaluating the Final Scientific Paper" (Table 3) to help them to determine whether or not their final paper was complete.

RESULTS

The pooled class data showed clearly the predicted circadian changes in autonomic, motor, and cognitive functions (Refs. 3, 5; Figs. 1–3). Function was greatest during the normal activity period (~0600 to 2200), with pulse rates of ~80 beats/min (Fig. 1), the adding of a column of numbers requiring only 55 s (Fig. 2), and excellent eye-hand coordination in which the correct count was generally completed on the first or second try and requiring only 15 s for a correct trial (Fig. 3). In contrast, all measured variables showed decreased activity during the normal rest period (2200 to 0800). Pulse rate decreased to a low of 65 beats/min (Fig. 1) and adding speeds became very long (65–80 s), with a particularly long time required to complete the task at 0200 (110 s; Fig. 2). Eye-hand coordination was also greatly reduced during the rest period. It required 20–40 s to complete a correct trial, and invariably more than a single trial was required to produce a correct count (Fig. 3). These general patterns in the data were easily recognized by the students and could be compared with readily available literature on circadian rhythms for discussion in their scientific papers.

The middle of the activity period was also associated with a change, although less dramatic, in the measured functions (Figs. 1–3). These changes occurred

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**TABLE 2**

Checklist for evaluating the discussion section

<table>
<thead>
<tr>
<th>Instructions: Use the checklist below to analyze the sample discussion or your own or your peer's discussion section. In the discussion section, the writer should interpret the results and explain how they relate to the existing literature on the topic. A good discussion section should include:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. A general statement about the results of the study. Has the writer presented a general statement about the results of the investigation in the first paragraph?</td>
</tr>
<tr>
<td>If the answer is YES, underline the details.</td>
</tr>
<tr>
<td>2. The results of the study in more detail. Has the writer presented specific results from the study?</td>
</tr>
<tr>
<td>If the answer is YES, underline the details.</td>
</tr>
<tr>
<td>3. An interpretation of the results without any reference to prior research (what do the results mean?) Has the author interpreted the results?</td>
</tr>
<tr>
<td>If the answer is YES, underline the interpretation.</td>
</tr>
<tr>
<td>4. A comparison and contrast of the results with results from prior research cited in the introduction. Has the author explained how prior studies support or reject the results of this study?</td>
</tr>
<tr>
<td>If the answer is YES, underline what prior studies have to say about the results of this study.</td>
</tr>
<tr>
<td>5. A discussion of any problems in the data collection process and how they might be corrected in future research. Has the author discussed any problems in the data collection process and how they might be corrected in future research?</td>
</tr>
<tr>
<td>If the answer is YES, underline any problems in the data collection process and discuss how they might be corrected.</td>
</tr>
<tr>
<td>6. A conclusion that can be drawn from the results of this investigation. Does the paper include a conclusion paragraph?</td>
</tr>
<tr>
<td>If the answer is YES, underline the conclusion.</td>
</tr>
</tbody>
</table>
at 1400, the data point that followed the normal lunch hour. Pulse rate increased slightly to 85 beats/min (Fig. 1), adding speed increased to 75 s (Fig. 2), and eye-hand coordination decreased, such that it required over 20 s to complete the correct count (Fig. 3). These changes in bodily function were not as obvious to the students and were only rarely mentioned in the scientific papers.

**DISCUSSION**

General education students appear to be genuinely interested in this exercise and so become willing participants in the experiment and the subsequent writing assignment. The experimental demonstration of a circadian effect on all measured variables is quite reliable, both across laboratory sections and from quarter to quarter (data not shown). In addition, students have an “intuitive” feel for the outcome of the experiment before they begin their data collection. We have found that this ability to reliably predict results is important in introducing nonmajors to the scientific method and maintaining their interest in the project, because it allows them to better understand certain experimental procedures. For example, students easily understand that data collected from people who are shift workers must be eliminated from the data set or the trends in the data may be masked. They do not complain that we are “biasing” the data set by this manipulation.

The typical laboratory class of 15–25 students provides an adequate sample size for this exercise, even when data from shift workers are eliminated. The students obtain a rudimentary concept of individual variability from this sample population, but still recognize the overall trends in the data. They routinely note the predicted decline in function during the normal rest period and augmentation of function during the normal activity period and discuss these trends in their papers. We have not yet required any statistical
FIG. 2. Circadian influence on adding speed for a single introductory biology laboratory section (n = 16 students; awakening time = 0600–0800, bedtime = 2200–2400). Adding speed was the time required in seconds to add a column of 19 single digit numbers.

analysis of the data because the students' mathematics backgrounds vary dramatically. However, a simple t-test could be used to compare the maximum and minimum values for a given variable.

The library exercise is an essential component of this quarter-long project because there is great variability in the computer and information literacy skills of the general education student population on our campus. The required exercise ensures that all students have the basic skills required to retrieve information that can be used to explain their own experimental results and produce a journal style article. We purposely restrict the acceptable sources to secondary references because many of the students do not have the academic background to make adequate use of the primary scientific literature. However, when individual students show a level of sophistication that indicates they are capable of understanding primary sources, we always approve those sources for inclusion in the paper. For example, many senior psychology majors ask to include primary sources. We also make available, through the limited-loan desk in the library, some recent references that help students put the exercise into a practical context and start thinking about how to frame their introductions and discussions [7, 9].

FIG. 3. Circadian influence on eye-hand coordination for a single introductory biology laboratory section (n = 16 students; awakening time = 0600–0800, bedtime = 2200–2400). Eye-hand coordination was measured in 2 ways: time in seconds to achieve a correct count to 25, as indicated in Ref. 4, and the number of trials in which there were mistakes before achieving a correct count.

Besides promoting the development of computer database research skills applicable to the scientific paper assignment, the library exercise promotes the acquisition of library research strategies transferable to general education courses other than biology and to writing tasks different from the scientific paper. This is accomplished by promoting training with awareness that involves instructing students in what search strategies to use, how to use them, and when to use them [1].

Instructors in introductory level general education biology courses are faced with multiple in-class demands that include, but are not limited to 1) teaching content-related materials, and, as is the case in this course, 2) modeling the scientific paper assignment. Given these competing demands, it might not be possible to conduct the in-class activities developed for the adjunct study group. For example, we have
been unable to make use of the study group activities since winter quarter 1994. However, because general education students greatly benefit from tasks that go beyond requiring them to simply become aware of the demands of the weekly writing assignments, out-of-class activities could be developed that involve the use of checklists (Table 2; checklists for other sections are available from Project LEAP; Library South, Palmer Wing, Room 1062A; California State University, Los Angeles; Los Angeles, CA 90032) as a means to help students reflect on and assess their writing processes. The use of the checklists would serve two specific purposes. First, it would give students valuable information regarding the extent to which their writing matches the demands of the weekly tasks and whether revisions are in order. Second, the use of the checklists would help the instructor understand whether their students' perception of their writing process is accurate and whether the instructor needs to make adjustments to his/her own teaching process.

The multistep writing project represents a significant commitment of time by both students and instructors, but produces a valuable finished product. The multistep nature of the assignment, which provides students with opportunities to develop their academic literacy skills within an apprenticeship framework (2), requires a long-term commitment by the students and the instructor to the improvement of academic literacy skills. Generally, students respond to the feedback on the drafts in a positive way and the result is the production of a truly scholarly final product. These final papers would be appropriate for inclusion in portfolios on campuses that make use of portfolio assessment as a criterion for graduation.

The requirement that the paper follow typical scientific journal-style writing ensures that the students will relate other previously published work to their own experimental results and then place both types of information into a broader context. General education students are introduced to the culture of science because they must first conduct a controlled experiment and then reconcile their results with other published results, as a practicing scientist would. However, they are also given the freedom to explore how science impacts their discipline by framing their paper in any context that can be adequately defended. For example, business majors are often intrigued by the implications that circadian rhythmicity has for companies that employ rotating shift workers or that send CEOs on trips across multiple time zones, while future teachers are interested in the implications for design of efficient school programs. This flexibility is essential to maintaining high student interest in the project and ideally will give general education students a positive first experience with science.

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