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A Picture is Worth 1000 Words: Teaching Science Communication with Graphical Abstract Assignments

Swati Agrawal[a] and Paul Ulrich[b]
[a]Department of Biology, University of Mary Washington, Fredericksburg, Virginia, USA
[b]Department of Biology, Georgia State University, Atlanta, Georgia, USA

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INTRODUCTION

Graphical abstracts as the norm in scientific publishing

The inclusion of graphical abstracts (GAs) as visual summarizations of research findings are increasingly common for many scientific journals (1, 2). These illustrations rapidly communicate the gist of research to scientific readers and are readily shared on social media platforms. Graphical abstracts facilitate browsing for experts and nonexperts in the field, for example, during the flood of papers released during the 2019 coronavirus disease pandemic. The amount of information published daily was overwhelming, but addition of graphical abstracts in many articles permitted readers to efficiently stay abreast of emerging data regarding vaccine targets or newly developing variants of severe acute respiratory syndrome coronavirus 2.

Why should we teach GA design in the undergraduate classroom?

Many biology courses focus on scientific literacy by teaching scientific communication as an essential element of scientific literacy. These skills can be taught in guided inquiry modules or course-based undergraduate research experiences (CUREs) through literature review, results presentations, and reports. The use of visual representations of data in the form of diagrams, pictures, infographics, and graphs are ubiquitous in scientific presentations (3, 4). However, instruction in most curricula overlooks teaching graphical designs as part of scientific writing. Consequently, most scientists have had very little experience in leveraging tools for visual content creation when it is time to publish their work. The task of presenting complex data is a daunting task for even advanced graduate students, and inclusion of a GA as an afterthought due to a journal requirement can produce an ineffective GA (5, 6). We recognized this training gap in our Molecular Parasitology CUREs across both universities (University of Mary Washington and Georgia State University). We addressed this deficit by integrating creation of graphical abstracts as a core element of the experimental design process, research plan communication, and illustration of results. We have utilized this approach with a total of 113 students over 6 semesters. Four examples from student projects are shown in Fig. 1.

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Address correspondence to Department of Biology, University of Mary Washington, Fredericksburg, Virginia, USA. E-mail: sagrawal@umw.edu.
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PROCEDURE

Students in the CURE were introduced to the idea of GA at the beginning of the course through journal clubs or a research design module in concert with a short research proposal. While designing their research projects, students searched existing literature, formulated hypotheses, and established an experimental plan. In one assignment, students were asked to develop a GA for their experimental plan, communicating the assays used to analyze samples and highlighting treatment and control groups. A list of popular graphical design tools and guides was provided to students as a starting point (see the example assignment at the end of the article) (7). We gave students freedom to select software they were most comfortable with or felt would best serve their purposes. We have found it is not necessary to provide software-specific training with the wide range of tutorials available online. Overall, free resources such as Biorender have been overwhelmingly adopted by students for GA. We discussed general principles for GA design using the Cell Press guidelines.

All students were given feedback on their initial submission that they used for revisions. Compared to narrative formats, the exercise was formative for students because assessment was more efficiently assessed (see rubric, found under Supplemental File 1) and allowed quicker feedback to students than the narrative formats we had used previously. Commenting on a single

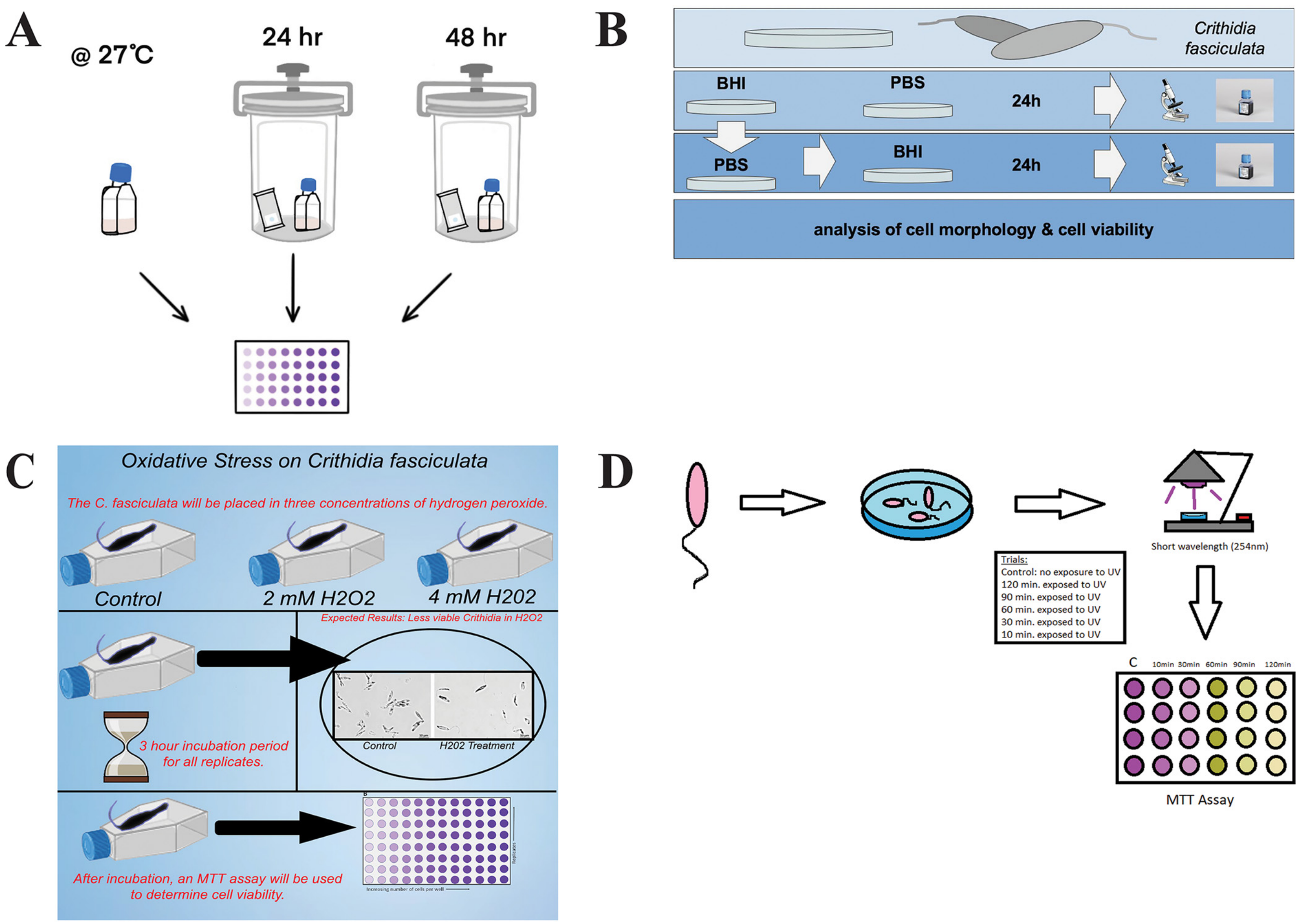

FIG 1. Examples of graphical abstracts from the Molecular Parasitology CURE. All projects in this CURE focused on *Crithidia fasciculata*, a trypanosomatid parasite that does not infect humans. (A) Effects of UV irradiaton-induced cell death. (B) Analysis of growth defects upon nutrient starvation. (C) Effect of hypoxia on growth and survival. (D) Sensitivity of *Crithidia fasciculata* to oxidative stress induced by hydrogen peroxide.

GA requires 5 to 10 min, but feedback was not limited to formal assessment. Conversations with students about GA were ongoing over the course of the semester and served as important reinforcement.

Perks for students and instructors

Students demonstrated increasing competence in graphical illustration and science communication as they refined GA over the semester, thereby linking the use of science practices and iteration characteristic to CUREs (8). For example, Fig. 2A shows the original submission from a group of students. The group initially forgot to include replicates, but a quick discussion during their presentation revealed this flaw and resulted in revision with the subsequent submission. Another example (Fig. 2B) shows another submission where students indicated inaccurate incubation time for a biochemical assay. Feedback from the instructor allowed students to modify their experimental timeline. Therefore, picturing a problem can be a much more helpful tool in aiding students to come up with a solution compared to feedback on a written report. Representative feedback from instructors on experimental design aspects of GA included, for example, "unclear what your independent variable is"; "since your project aims to measure lipid peroxidation, this should be included in the abstract"; and "your graphical abstract should be updated with incubation time for growth curve and MTT assay." Feedback also addressed graphical design aspects to improve impact: "use uniform font sizes"; "this is a good start but will benefit from eliminating redundant elements. . . duplicated lower panels"; and "you can remove redundant images of microscopes and pipettes to have more clarity and flow."

DISCUSSION

We also found that developing a research idea or experimental plan with multiple group partners through a graphical abstract was more fun and provided a feasible way for students to collaboratively contribute to the project. This was particularly important for our CURE, where students collaborated cross-institutionally. GAs allowed iterative improvement of research design and decreased the amount of review time

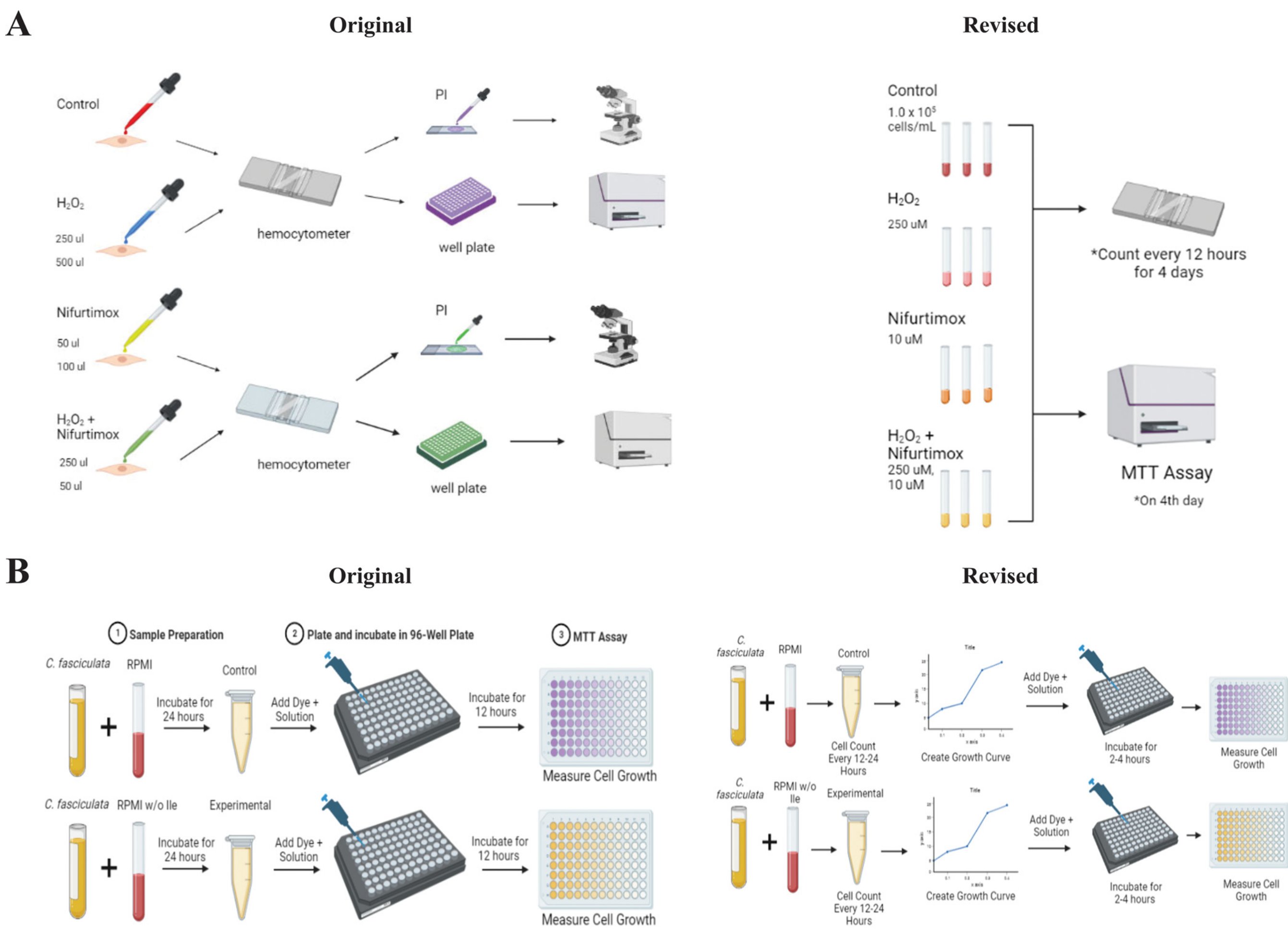

FIG 2. Students improved the quality of their graphical abstracts with revisions based on instructor feedback. (A) An original abstract submitted by a student was visually cluttered, which was eliminated in the revised version. Note the student's attempt in the revised copy to convey replication and provide concentrations of compounds rather than volumes. (B) The original abstract submitted by this student, which did not include counting of cell densities. The revised version illustrates this experimental design aspect.

needed by the instructors or peers. Each group received formative feedback from an instructor. This allowed students a chance to quickly tweak weak points in their design. At the end of the semester, once students had conducted their research projects, they were also asked to integrate their results to summarize their findings. This final version of a GA was very similar to uses in scientific journals and proactively trained students for a career where GAs are commonly encountered.

Sample assignment given to Molecular Parasitology students

An abstract of a scientific journal or a conference presentation familiarizes authors with the outline of the project, conveys important findings of the study, stimulates interests, and sparks collaboration. In the past decade, an increasing number of journals have encouraged the use of visual "graphical abstracts" to summarize scientific research. As one can imagine, the use of visuals in the form of diagrams, pictures, and infographics can allow readers to quickly browse and increases visibility of the paper to both researchers and social media. For this assignment, you will design a graphical abstract with your project partner (Assignment 1). You will modify your graphical abstract later in the semester to encompass the changes you make after the first iteration of the experiment (Assignment 2).

Assignment 1: graphical abstract for hypothesis and experimental design. Below are some required readings before you start your graphical abstract.

- Attract readers at a glance with your graphical abstract (http://crosstalk.cell.com/blog/attract-readers-at-a-glance-with-your-graphical-abstract)
- Cell Press graphical abstract guidelines (http://www.cell.com/pb/assets/raw/shared/figureguidelines/GA_guide.pdf)
- Example paper with a graphical abstract [https://www.cell.com/fulltext/S0092-8674(15)01570-6]

A good graphical abstract has all the necessary components of the experimental process without clutter or too many distractions. Once you get a sense of what graphical abstracts are, start designing yours; I suggest you draft one on pen and paper and discuss with your project partner and peers in the class. Consider the following platforms to start building yours. Feel free to explore other tools as you like: Biorender, Blender, Adobe Illustrator, 3D Max, and GIMP.

Assignment 2: graphical abstract for data and results presentation. For this assignment, review and incorporate all changes necessary suggested for assignment 1. Pay special attention to spelling mistakes, replicates, controls, and organization of your experimentation process. Now summarize and add representations of the most important data from your research findings to convey the "bottom line" of your research.

SUPPLEMENTAL MATERIAL

Supplemental material is available online only.

SUPPLEMENTAL FILE 1, DOCX file, 0.01 MB.

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