If They Build It
Student-Designed Assignments in a Molecular Biology Laboratory

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Abstract
In an undergraduate biochemistry and molecular biology lab course, students designed their own final assignment to communicate their laboratory work to non-disciplinary audiences. A "meta-assignment" guided them as they proposed the content, form, and process requirements. Students strove to develop unique ideas, and all successfully completed their self-assigned projects. Providing students in this class with the freedom, responsibility, and appropriate scaffolding to build their own projects and learning experiences allowed them to interact with their discipline in new ways and enhanced their abilities to design and plan their work, communicate scientific ideas to nonscientists, and think creatively.

Reflective Essay
Giving students more control over their work can enrich a classroom (Boersma et al., 2001). Here, I describe a nested assignment in which students design and propose their own writing projects and then complete them. In this activity, the student, rather than the instructor, decides the product of the assignment, the process by which they will work on the assignment, and the parameters by which the product should be judged. My experience teaching this assignment has suggested to me that when students define the expectations and outcomes of a learning activity, they take greater ownership over their academic experience, enhance their project planning and management skills, and deploy creative forms of communication.

I first asked students to design their own assignments in a writing-intensive laboratory course in molecular genetics at Penn State Berks, a small college in the Penn State University system. There were sixteen students in the class, all majors in biochemistry and molecular biology, all graduating seniors. In this de facto capstone course, students spend most of the semester on an extended lab project that integrates theory and technique and involves both wet work and computational biology. To complement the notebooks, lab reports, and problem sets that form the backbone of assessments in the course, I sought an activity that would engage them in a unique way. In prior offerings, I had found that seniors looking forward to commencement could become distracted from their classwork. In addition, I presumed that in postgraduate school or in the workplace, they would be taking more responsibility for planning, executing, and assessing their work. I sensed that students at this stage of their education were ready for a different kind of assignment: I wondered, specifically, if my detailed learning objectives and finely gridded rubrics were overly prescriptive, possibly even stifling, to students who were ready to grow as independent thinkers. As Anderson and Krathwohl (2001), in their seminal revision of Bloom's taxonomy, put it: "Not all important learning outcomes can, should, or must be stated as a priori objectives" (p. 21). I wanted to provide "a *direction* for learning, but not a particular *destination*" (p. 21).

Furthermore, I wanted to encourage them to expand their understanding of how to communicate science. Although lab reports and PowerPoint talks are sturdy, dependable frames

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for showcasing disciplinary knowledge and practicing writing within the conventions of their field, there are benefits to students learning to present and interpret their work through other forms and to other audiences. For instance, those trained in the discipline increasingly have been called upon to translate science to the public (Brownell et al., 2013; Greenwood & Riordan, 2001). Communicating to a nonscientific audience requires "deliberate practice and careful attention to language" as well as an expanded rhetorical awareness that will serve students in future contexts in science and beyond (Brownell et al., 2013). Presenting to non-specialists also gives scientists at all levels an opportunity to reconsider and reengage with their work while serving out a "civic duty" (Greenwood & Riordan, 2001).

Therefore, rather than assign my students one final lab report, I asked them to design their own assignments, presenting their laboratory work from the semester in a format of their choice to an audience of their choosing. That year, their lab project involved cloning, sequencing, and analyzing a series of plant genes that encoded glyceraldehyde-3-phosphate dehydrogenase, a commonly studied housekeeping enzyme, to allow determination of evolutionary relationships among the plants. The project was based on approaches described by Lau and Robinson (2009) and Hall (2013). I instructed the students to tell the "story" of this lab work, to consider how they wanted their story to be evaluated, and to devise a workplan for creating, revising, and refining their story. By referring to what they were making as a story rather than a report or manuscript, I hoped to guide them away from academic and disciplinary forms and toward reflecting on their lab work not only as a collection of procedures, experiments, data, and ideas, but also as an experience.

I had set them loose to wander territory that was likely unfamiliar and perhaps unsettling. As a kind of map, I gave them a "meta-assignment" that I hoped would enable them to explore without imposing undue constraints on them. This assignment about the assignment they were to design instructed them to generate proposals in three parts. The first part described what content they were planning to include, how they would tell their stories, to whom and for what purpose—a recast version of John Bean's (2011) "RAFT" for writing assignments that defines a role, audience, format, and topic for student writing. In this case, however, students built their own RAFTs. I suggested possible forms, genres, and media: a recorded TED talk? an interview? an article in a popular science magazine? (Lab reports, posters, and PowerPoint presentations were not forbidden, but students agreed that those did not represent the most interesting possibilities.) I also emphasized they could choose other forms as their imagination and judgment allowed. Their audiences could range from young children (a challenge for the budding molecular geneticist) to a peer group with expertise equal to theirs. I asked them to envision the situation surrounding their storytelling and the purpose of their communication. What they presented would be their lab work, of course, but they would choose the scope and the level of detail. Providing students with control over and responsibility for these components forced them to reckon with how the parts of a RAFT are connected and interdependent.

In the second part of their proposals, students constructed rubrics for the assessment of their own projects. I hoped that describing important measures of achievement in their proposed work would further help them conceive of the dimensions and shape their work ultimately might take. This aspect of the proposal was not intended to teach students how to make a rubric, but to encourage them to think about, as they were planning their project, how they would like it to be evaluated. Suggested rubric categories included the breadth, depth, and/or accuracy of their technical content; the focus, clarity, and organization of the presentation; elements of style; and mechanics.

In the proposal's third section, students outlined a workplan. They could work with a partner or alone; most chose to work with the partner they had been paired with throughout the semester for lab work, but two students decided to work by themselves. Collaborators defined who would generate what content and how they would work together to revise and refine. They set deadlines and deliverables, including dates for drafts and peer and instructor feedback. In other words, they took responsibility for managing the workflow of this long-term project.

I stipulated two requirements, which I intended as guardrails to keep the students on track. First, I told them I needed to approve their three-part proposals. I gave them hard deadlines for a draft proposal and, three weeks later, for final approval. Students then had, at minimum, three weeks remaining in the semester to execute the project. Proposal approval required several rounds of feedback and revision—this scaffolding was meant to ensure high-quality proposals from all students. For instance, I asked groups to think about what would make their telling of the story unique, or to reimagine the purpose of their communication (e.g. Why would employees of this hypothetical biotech company need to understand the particulars of this molecular genetics project?); or to adjust their format to speak to the audience more effectively, or more carefully consider the audience itself (e.g. Does the owner's age for this fictional Facebook page imply something about the friends he is speaking to?); or to rethink the kind of content that might be appropriate or possible for a given format (e.g. What topics are necessary and engaging enough to teach elementary school children the basic idea of gene cloning?). For this part of the proposal, I tended to offer feedback as a potential audience member rather than a genre expert; fortunately, students chose audiences I was familiar with and whose perspectives I could adopt. In response to the proposed rubrics, I guided students to expand categories (e.g."Grammatically correct" could be broadened to "clarity" and describe both text and diagrams.); better define the levels of mastery (e.g. Provide specific details to explain the difference between "not very organized" and "organized, but needs improvement."); recalibrate the weighting of categories (e.g. A product that's "successful" in a category should probably earn more than 75% credit.). Regarding workplans, I suggested how they could solicit feedback on drafts from their peers (even from outside the class) as well as from me or other faculty.

In addition to gaining approval of their proposals, students needed to work according to what they proposed. (Any substantive modifications to their proposal required reapproval.) I would assess each final product according to its corresponding rubric for two-thirds of the grade. The remaining one-third would reflect the student's ability to work as they had planned: a compilation of all drafts and feedback in dated order for each project was compared against its respective workplan. Thus, students were accountable not only for what they were proposing to make but also how they were proposing to make it. They were building their own learning structures.

Along with the meta-assignment, I provided an example I created of a full proposal with RAFT, rubric, and workplan (see Model Proposal). What I left out, however, was any particular expectation about what they would make. That discomfited some of them, but most took up the challenge without complaint. And once they started dreaming up ideas, they strove to develop their own original concepts. Many students adopted digital forms to tell their stories. The use of electronic media likely reflected their environment and upbringing and also anticipates the thinking, doing, and making in which they will engage in the future, where digital fluency will play an increasingly large role (Brown, 2006; Sparrow, 2018). All students made the project personal and—through cycles of feedback and revision as described above—thoughtfully considered role, audience, form, and topic. For instance, one student, who would enter business development after graduating, worked with another student to create media directed at a sales force pitching courseware to biochemistry lab instructors. In addition to providing a technical overview of the lab work they had done that semester, they surveyed their peers and instructor for input about the educational quality of the gene cloning, sequencing, and bioinformatics work and then packaged the content into a training video for the sales teams. Another pair of students, both of whom worked as ambassadors for our college's admissions office, created a glossy issue of a digital magazine featuring biochemistry labs to interest prospective students in the major. Using Microsoft Publisher, they assembled an overview of the scientific project and illustrations and descriptions of the various experimental techniques used in their bench work. They also included photos and short bios of themselves and described their future career plans and career outlook for students in the major. Another student chronicled her experiences throughout the semester in a series of emails to her nonscientist mother. This endeavor required translating jargon and explaining technical concepts in even simpler terms than the magazine and the training video. It also inspired this student to simultaneously tell the story of a semester in the life of a college senior. Other examples of student work in this class included a blog and a Facebook page for fellow science students, lessons to introduce molecular cell biology to school-age (K-5) children, and a whodunit graphic novella featuring department faculty and depicting the application of molecular biology to forensics.

Grades became less important in this milieu: students never mentioned them to me. They remained motivated, however. They addressed my suggestions on the first drafts of their proposals, and the second drafts, and the third. Everyone obtained approval by the deadline. And then they scrambled to outdo one another in executing their proposals. There was no strife either within groups or between individuals, but there was a spirit of competition in the class, perhaps reflecting their level of investment in the work. Everybody completed their proposed projects according to their plans. Seeing their engagement and excitement, I suggested we put on a showcase event for the science division. They agreed and, during the middle of final exams week, presented their projects in a mini-symposium attended by friends and faculty (many at the students' invitation) across the division and the campus.[1] After the showcase, the students completed an optional, anonymous survey, in which they unanimously agreed the experience had helped increase their creativity and prepared them for a more independent phase of their educational journey and even had increased their interest in molecular genetics. They expressed appreciation for the chance to develop their creative, collaborative, and time management skills and called it "rewarding," "challenging," and "fun." They talked about how it was "nerve-wracking" to work without structure, and how at the same time they "loved the freedom."

Like any learning activity, how students respond to designing their own assignment depends on context. Last year, I adapted the strategy of student-designed assignments in an upper-division seminar in structural biology.[2] In the survey described above, several of the molecular genetics students had suggested giving future classes more time to generate ideas, and so I introduced the meta-assignment to these structural biology students before the midpoint of the semester.[3] They did not begin working in earnest, however, until near the proposal due date, two-thirds through the term. Due to the COVID-19 pandemic, we had abruptly switched from face-to-face classes to meeting online, and the quality of their project proposals, despite my feedback, was uneven. I was disappointed but not surprised, given their procrastination and the challenges of maintaining engagement and communication in the emergency online learning environment. I decided to de-emphasize the proposals and instead asked students to present (through Zoom) their proposed ideas and preliminary work to me and their classmates for informal feedback. That is, we transformed the remote classroom into an online workshop, a digital studio (Brown, 2006). This additional (ungraded) requirement of presenting their early ideas activated the structural biology class. As they showed their works in progress through Zoom, students who had already devoted significant time and attention to the projects—and there were several—impressed their classmates. Students who had not—and there were several of those, too—sheepishly deprecated their own efforts. More importantly, they subsequently reconsidered their projects, in some cases submitting entirely new proposals to me.

After receiving feedback in this workshop setting, the structural biology students, like the molecular genetics students the year before, submitted final projects that reflected a high degree of creativity and investment: a podcast telling the story of genetically engineered insulin, a fable in which a medieval village falls victim to a disease caused by proteinaceous infection, a virtual museum of protein structures toured from a first-person perspective. There was a concept for a Disney Epcot-like attraction that would entertain and educate theme park guests by engaging them in a game that simulated, in impressive detail, proteins being assembled, folding, and interacting with one another. This project included a portfolio of drawings depicting the overall layout of the exhibit, the various stages of the game itself, an anthropomorphized double-helix mascot named Eugene; a written statement describing the genesis and evolution of the ideas; and a three-dimensional scale model of the entire gaming station. In other words, the effort revealed the student's interest in themed entertainment design and his artistic and scientific talents, and also a motivation to exceed not only my (and his) initial hopes for the project, but to surpass even my (and his) increased anticipation following the presentation of his preliminary sketches and drafts. Other course components—homework, seminar discussions, problem sets, cumulative exams—evaluated the depth of the students' disciplinary knowledge; these submissions showed not only how the students learned to convey those complex scientific concepts to nonscientist audiences but also how engaging students' creativity can enhance their interaction with a narrow, specialized discipline.

The usefulness of the workshop component in the structural biology course suggests other ways to adapt and improve student-designed assignments. Although I have asked students to include peer review in their workplans, instituting a more formal peer review process could add another layer of "nesting" to the experience. Greater emphasis on peer review—with guidelines for effective review—would provide students with additional early feedback on their proposals and projects while building their communication and collaborative skills (Nilson, 2003). It also could help reviewers see the assignment and their own proposals and projects from a different perspective. For projects with nonscientist audiences, incorporating reviews from readers and viewers outside the class would encourage students to consider even more carefully how to reach their intended audiences and how to better align their standards of evaluation to them. Although the rubrics worked well enough for my grading the projects, students have tended to emphasize typical writing elements regarding content, organization, style, and mechanics. While students are not necessarily training to become teachers (and rubric-makers), having them more intentionally define how their work might and should be received and judged by the people they are targeting should further deepen the experience.

Instructors are always balancing objectives and detailed directions against creativity and independent thinking—creativity, after all, depends on structure (Goldenberg et al., 1999)—and we have to weigh things differently for seniors and first-years, in small classes and large, for different disciplines, different courses, even different sections of the same course. Whether any lesson "works" in a given context depends on many factors. Regardless, my experiences with student-designed assignments demonstrated to me the value of exploring different ways to define (or not) expectations in a variety of situations. From an essay question on a final exam asking general biology students to nominate a creature for "most awesome organism in the world" to incorporating a semester-long undergraduate research experience into a lab course (Auchincloss et al., 2014), I have tried to give students the room and the materials to build. And, with the right guidance, they have responded. By both providing structure and clearing space, and by doing so with intention and care, we can create places with the potential for deeper engagement, surprise, and delight—for us and for our students.

ASSIGNMENT

Meta-Assignment

Overview

In the final project for the course, you'll design your own assignment and then create an original work to complete your assignment. This "product" will tell the story of your GAPDH molecular cloning and bioinformatics work this semester. You'll tell the story in a format of your choice, to an audience of your choice. You will also decide how to evaluate the success of your storytelling.

You'll start by developing a project proposal, which I must approve, and then you'll develop the product itself. Both the product and the process by which you create it are integral to this project.

You may work with a partner or you may work alone for this project. If you choose to collaborate, both of you will receive the same grade.

Rationale

This final project is a bit out of the norm for me, and perhaps for you, too. Since many of you are nearing the end of your college career and will be moving into a more independent phase of your educational journey, I want to give you the freedom and responsibility to develop your own learning experience. Through this activity, I anticipate you'll increase your competency in project design, planning, and evaluation and improve your ability to communicate scientific knowledge. I also hope that in developing your own project and by generating work that's more "creative" than, say, a typical lab report, you'll gain a broader perspective on science, communication, and learning itself.

The Project Proposal

There are two hard-and-fast requirements for this project: I must approve your proposal, and you must work according to what you propose. If, in the course of creating your product, you wish to alter your approved proposal, I must approve the modification.

Developing the proposal will take some brainstorming (maybe a bit of daydreaming?) and some outside research. Approval will likely require multiple rounds of drafting and revision. Develop your proposal as soon as possible and gather feedback on it from me, your classmates, and other interested parties.

Your project proposal will describe the product you wish to create, the rubric against which your product will be evaluated, and the process by which you will create the product. Each of these components is described below.

Proposal Part 1: What will you create?

Imagine what your final product looks like. What's your story? Who are you speaking to, and why? How will you tell your story? These questions (detailed below) are interrelated—so as you refine and reimagine your product, you'll want to consider these elements in combination.

1. Content: What will you present?

Naturally, you'll be communicating essential aspects of your work with GAPDH cloning and plant phylogeny, but you'll need to decide the scope and depth and how to frame your story. Some of you will want to include some of the fine details—for instance, the use of the Eco47IR gene as a selection tool for subcloning, or BLASTing a genomic query sequence against the mRNA database to identify the intron-exon boundaries, or how MEGA aligns sequences and calculates a phylogenetic tree. Others will use broader brush strokes to provide a higher-level description of the work.

What you emphasize will depend on your audience, format, and purpose.

In your proposal, define your content as precisely as you can—that will make it easier to create your product.

2. Format: How will you tell your story?

    You may present your story in any form using words (written or spoken). You may also use graphics or multimedia, but don't tell your story solely with visual imagery.

    Some options: a nonfiction article (for example, for a popular science magazine), a creative essay, an exchange of letters, an interview (written or filmed), an instructional resource or teaching guide, a PowerPoint or TED talk, a video essay, a graphic novella, a poster, a website, or . . .

    As you decide on the genre and media for telling your story, explain why that form is particularly suited to your content, audience, and purpose.

    By the way, you should have some familiarity with the genre / media you choose—or at least a willingness to learn about it!

    Again, providing specifics here will help you think out possible directions for the project and pave the way for the product creation phase of the project. Include an approximate length to help define the scope of your work.

3. Audience: To whom will you speak?

    If you choose a more creative genre, you may be presenting to a lay audience who has little knowledge of molecular genetics. More technical forms might target other potential students in the course, or even instructors.

    As in the example below, you may speak to yourself, but not solely to yourself. Or you may wish to speak to a particular person important in your life or choose a wider audience. Depending on your project's format, you may define more than one audience.

4. Purpose: What do you seek to accomplish with the work?

    To inform? Entertain? Persuade?

    Your purpose in telling a story is tied to the way you tell it and to whom—and what story you ultimately tell.

Once you've answered these four questions for yourself, describe your responses in your proposal. Start with an overview that shows how these elements of the story are interconnected in your proposed work. Then explicitly describe each of the elements (not necessarily in the above order).

Proposal Part 2: How should your creation be evaluated?

Define the criteria by which you will define success. Consider aspects of the work such as the quality and development of ideas—this could be the accuracy, scope, and depth of technical content; how you frame your argument (the background and rationale); focus and clarity and the logical connection between your main ideas and supporting details. You might also think about presentation style, mechanics, and/or other appropriate categories.

Assemble a **rubric** based on these criteria.

First, define the criteria and the characteristics of a successful product. Include categories that address the scientific content, the quality of communication, and the impact of the work. Within each category, you may define the various levels of achievement—for example, what constitutes "A" level work, "B" work, "C", etc.

Then, if you desire, weight the categories in your rubric as you see fit. Or you may choose not to define weights if you believe your work should be evaluated in a more comprehensive or holistic manner. (The example below uses a holistic rubric.)

Proposal Part 3: How will you create this work?

As you probably know, a plan helps you organize, manage, and hold yourself accountable. Draft a **workplan** that will keep you on track for successfully completing the project.

This workplan should detail deadlines and "deliverables." Deliverables will include the outlines, storyboards, rough drafts, sketches, etc. that you'll create as you progress through the project.

Deliverables also include self-assessments, peer feedback, and instructor feedback that you'll use to guide your revisions—you must include each of these elements in your proposal for approval.

If you're working with a partner, please indicate this. Also, detail in your workplan who is responsible for what.

At the end of the project, in addition to the final draft of your work, you'll submit a portfolio that includes all formative works—drafts, feedback, etc. with the dates of completion. (Save copies of everything!)

Grading

I'll evaluate your project on the final product (judging it against your rubric, 100 points) and the process by which you created it (judging your portfolio against your workplan, 50 points).

I'll also ask you to evaluate your final project experience. This will give you an opportunity to reflect on what you learned and will help me assess and revise the project for the next class of students!

Notes

[1]Fifteen students participated in the showcase. One student missed the event when he was called away at the last minute to pick up his grandmother at the airport; she was flying in for the graduation ceremony three days later. He apologized to me and his partner, profusely.

[2]I also introduced the idea of student-designed assignments in the molecular genetics lab course again, but as the COVID-19 pandemic developed, the class decided on a different final project instead, one in which students collaborated on creating a website about the coronavirus and the disease.

[3]In the prior offering of the molecular genetics lab, I had scheduled the introduction of the final project so that students already would have completed much of the wet work. Although they had not yet started the bioinformatics phase, they proved able to include that additional content into their final projects. Thus, I felt comfortable introducing the final project idea earlier in the structural biology class.

Supplementary Material

For supplementary material accompanying this paper, including a PDF facsimile of the assignment description formatted as the author(s) presented it to students, please visit https://doi.org/10.31719/pjaw.v5i2.85.

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