Putting Science in Black and White: Intensive Technical Writing Through Non-disposable Assignments as a Path for Decolonizing STEM

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Humanity demands science, technology, engineering, and math (STEM) that can nimbly respond to its global health, economic, and environmental challenges. Unfortunately, as argued by Alo Basu (2021a, 2021b), the lack of gender and, especially, racial diversity in STEM disciplines threatens progress by the continued reliance on structural mechanisms for hoarding opportunity, which ultimately stifle innovation. Based on data from the United States Bureau of Labor Statistics (2020, 2022), employment in STEM disciplines offers greater earning potential than non-science or technology related occupations. Considering such a financial incentive, the fact that graduation rates in STEM disciplines (Riegle-Crumb et al., 2019) are lowest for women and people of color suggests they are blocked from access. Indeed, while they represent 28.7 percent of the population, underrepresented minorities (American Indian, Alaska Native, Black or African American, and Hispanic or Latino) obtained only 14.2 percent of doctoral degrees in science or engineering between 2019 and 2020 (NCSES, 2020). Further, while women earned nearly half of doctorates in that time frame, they constituted only one-third of doctorates in physical or earth sciences and merely one-quarter of doctorates in engineering, math, or computer sciences. At the same time, the diversification of these fields offers several advantages for both historically marginalized people and the general population. For example, in healthcare, which is dominated by white cis-male medical models, there is a particularly urgent need to address health disparities by the inclusion of diverse female and racial perspectives. Additionally, prevailing evidence of the "edge effect" —where creative solutions are likely to emerge from multicultural collaborations—suggests that only a diverse body of STEM practitioners can yield the necessary innovation to address pressing global challenges such as climate change.

A brighter future requires our deliberate and relentless cultivation of inclusion in STEM, beginning with education (Basu, 2021a, 2021b). How do we interrupt the process of STEM attrition, enable more minorities to flourish in that arena, and achieve the richly diverse perspectives needed for future innovation? In this

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chapter, I argue that writing through non-disposable assignments (NDAs) can be an effective means for chipping away at the inequities that block diversification in STEM. I, with Shannon Stock (Seraphin & Stock, 2020) and others (Seraphin et al., 2019), propose that in contrast to assignments that are discarded at the end of each semester (e.g., quizzes, individually-prepared term papers, or lab reports), NDAs (assignments that are prepared through peer-collaboration or produce publicly disseminated learning objects) have the potential to enhance student learning and retention outcomes in the culturally responsive classroom while sustainably generating useful applications or new tools that can benefit society. Like the meaningful writing projects highlighted in the work of Michelle Eodice, Anne E. Geller, and Neal Lerner (2017), NDAs also have the potential to be transformative for student learning and engagement.

In this chapter, I begin by defining NDAs, first in the context of the Open Pedagogy movement and then using a six-leveled, three-dimensional (6x3D, nonagonal) framework through which they can be considered. Once we have observed that learning objects represent the tangible outcome of NDAs, writing will be presented as the ultimate learning object. Next, I describe how the writing powers of STEM students can be shaped to meet course grading specifications through a three-stage process, using examples and student feedback from my own teaching of a recent neuroscience course. Finally, I address the question of "Why teach writing through NDAs as a means for diversifying STEM?" by invoking my own marginalized perspective as a teacher-scholar navigating the intersectional identities of a Black woman, immigrant, and mother reentering the workforce.

Non-Disposable Assignments: A Tool for Breaking Barriers Through Open Educational Praxis

Information enthusiasts may agree that knowledge should be freely shared for the benefit of all humanity. Indeed, Maha Bali, Catherine Cronin, and Rajiv S. Jhangiani (2020) argue for a social justice perspective on open education. Open educational practice is characterized by an application of instructional methods and the integration of teaching materials that are broadly distributed and commonly shared. These often free and reusable teaching resources and techniques represent "learning objects" (Retalis, 2003), constituting what is generally referred to as an Open Educational Resource (OER). In this spirit, an expanding culture of openness governs the creation and use of vital educational tools that are OER. Pedagogical practices advancing the objective of openness include those that either generate OER or facilitate the transfer of acquired knowledge between students, outside the academy, and even globally. The OER used in STEM courses may range from large course apparatuses and designs (i.e., learning management course templates, course syllabi, textbooks) and moderately sized course content (instructional materials, assessments) to granular course components (individual course elements such as slides, illustrations, simulations). These OER traditionally originate with field experts in academia or publishing but are also amenable to student creation, modification, and reuse. Student-generated instructional materials, developed through "renewable" or "non-disposable assignments," represent some of the best examples of culturally rich and effective learning objects available for blended learning (Alvarez, 2013; Falconer & Littlejohn, 2007). Furthermore, I suggest that the potential of OER depends on the pedagogical practice of using NDAs, which can sustainably generate the large number of learning objects of diverse origin that are needed for future open education. After many years of using group writing NDAs in anthropology, biology, neuroscience, and psychology courses, I can identify several assignments that both fulfill the objectives of open education while providing useful writing practice. These assignments vary in the gravitas or temporal and spatial reach of learning objects or deliverables. They also represent possible entry points for instructors wishing to experiment with this approach.

As formative assessments that shape individual practice, NDAs can be conceptualized through a 6x3D or nonagonal framework with learning products spanning six levels (i.e., Peers, Class, College, Community, National, International) across three key dimensions (Time, Space, and Gravity) (Seraphin et al., 2020). This framework is illustrated in Figure 9.1, which has been adapted from Seraphin et al. (2020). On the X-axis of *Time*, NDAs are marked by openness because they self-perpetuate through direct adoption, customization, and reuse. Since OER are easily modified to suit current learning objectives, they exhibit shelf lives surpassing the ordinary limitations of copyright and traditional publication-expiration cycles. For example, a learning object or teaching resource that was created and shared by a colleague last year could be customized by another for deployment in a new course and even further modified for future reuse as teaching needs or standards change. On the Y-axis of *Space*, OER also circumvents the physical and social structural boundaries that normally confine information within closely guarded spaces. Learning transfers across and transcends the usual margins separating those inside/outside the classroom, institution, community, and nation. For example, a learning object or teaching resource that was created and shared by students in one class can be adopted, modified, and reused in informal as well as formal educational circles—eliminating the longstanding identity- or affinity-based barriers of privilege. This includes barriers such as the English language supremacy identified by Elizabeth Blomstedt and bias against non-Western epistemological science challenged by Alicia Bitler and Ebtissam Oraby (both in this collection).

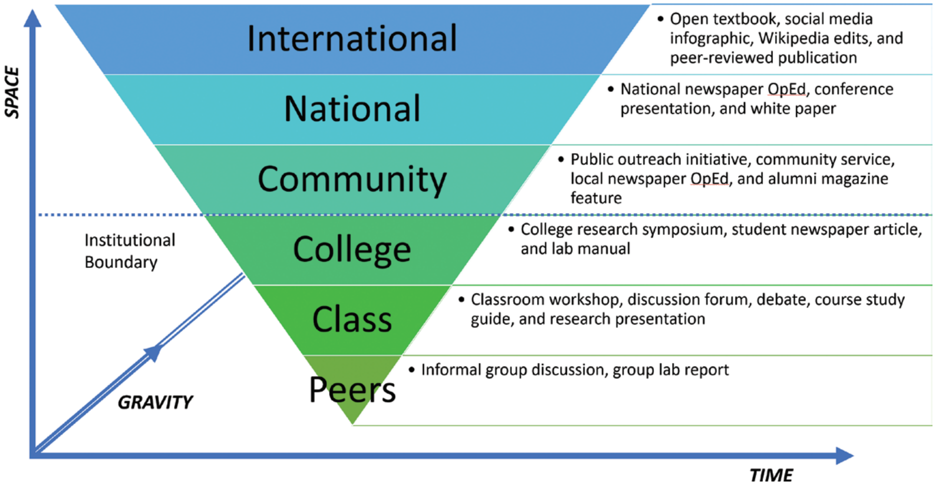

Figure 9.1: The space-time-gravity continuum for non-disposable assignments (NDAs). Adapted from Seraphin et al., 2018.

NDAs yield results in the form of learning objects that can be of tremendous value to students, their communities, and society. Thus, their *Gravity* can be viewed as proceeding along an imaginary Z axis whereby the results of open pedagogy have varying gravitas or significance, as determined by the degree of impact on the individual creator or a shared knowledge base. Depending on the information conveyed and the stakes involved, the learning object, for instance, a scientific meme about climate change, can simply educate or even serve to mobilize activism around causes such as the climate crisis and environmental justice. In this way, students develop important literacy skills while generating texts that reflect their unique ideas and diverse perspectives.

The most common NDA used in STEM courses unfolds at the level of Peers, where student–student teaching occurs through informal discussion, planning, and collaboration on learning objects, such as lab reports, shared among group members and with the instructor. Despite having the smallest temporal and spatial reach, the "Peer Level" NDA is foundational because it emphasizes peer-collaboration, elevating student perspectives and decentering the instructor. Being largely informal and contained between the peer-peer-instructor triad, this may provide a safe space for underrepresented students to experience the freedom of articulating their viewpoints and practice skills necessary for eventual success, with NDAs offering broader reach. It is important to note that the critical distinction making a lab report an NDA is this group requirement—which removes it from the realm of typical disposable assignments relegated to the classic student–instructor dyad.

At the "Class Level," NDA deliverables emerging from asynchronous discussion forums, synchronous learning activities such as workshops, debates, study guide development, and research presentations have an intermediate impact within the college. At the "College Level," NDA writing could generate learning objects for a public research symposium, student newspaper article, or reusable laboratory manuals and protocols. "College Level" NDAs have the greatest impact within that imagined or real physical boundary between the institution, its affiliates, and outsiders. While they have spatial reach across departments, student cohorts and may be preserved, the learning objects may remain confined to the academy.

Community-based learning or service-learning opportunities are increasingly demanded for college students. Through partnerships between the institution and community stakeholders, "faculty [are] able to take the classrooms out into the city and bring the city into their courses," according to Davarian Baldwin (2021, p. 68). Such new initiatives enrich student learning objectives by imparting a sense of meaning and the added purpose of serving the public good. Community and service learning also function to better engage the surrounding people and neighborhoods that are often adversely impacted by the so-called "Ivory Tower," which has an "elitist tradition of enclosure" (Baldwin, 2021). "Community Level" NDAs help to bridge the town–gown divide by generating learning objects that support public information or construct new channels of communication between entities ordinarily separated by college walls. By writing with, to, and for the benefit of their surrounding community, STEM students directly challenge the elitist tradition of enclosure. While working in close collaboration with community partners, students can generate research reports to facilitate their organization's mission. For example, through NDAs, STEM students can develop and disseminate scientific learning modules for use in public schools or craft op-eds to inspire public engagement around health and environmental problems. For example, students in my social neuroscience course recently partnered with community youth to build understanding on the developmental neurobiological impact of peer-bullying via learning objects they created. Their work was, in turn, celebrated in a college alumni magazine article by Andrew Concatelli (2023). In highlighting their science advocacy and community involvement, STEM students can appeal to their alumni and trustees on the mutual benefits from inter-collaboration (as opposed to coexistence) and begin to erase the legacy of suspicion between 'town and gown.' In a predatory trend, higher educational institutions have partnered with cities in building "technology communities" or "knowledge districts" that ultimately generate college revenue at the expense of surrounding neighborhoods under the guise of urban revitalization (Baldwin, 2021). Restoratively, STEM students can use NDAs to contribute to the communities they serve by generating learning objects through a fair process of exchange.

The broader the geographic reach of STEM student writing accomplished through NDAs, the more altruistic or intrinsically motivated is the endeavor as reciprocal demands from an identifiable stakeholder become impossible. By this ultimate service to humanity at large, STEM students can generate objects for learning that open higher education up to anyone with access to the internet nationally and internationally. Examples of "National Level" NDAs include a white paper describing a policy issue that can inform government deciders, a professional academic society or undergraduate research conference presentation, or an op-ed in a national newspaper.

At the "International Level," written NDAs can take the form of an open textbook, social media infographic, a peer-reviewed publication, or editing Wikipedia for accuracy. Depending on the mode of dissemination, the learning objects created at these final levels have excellent reach and greater permanence. For example, infographics made to inform the public on an issue can live on the internet forever once distributed through social media (e.g., Facebook, X/Twitter, Instagram, Pinterest, Tumblr), but their global accessibility depends on the route and frequency of redistribution. Contrastingly, Wikipedia edits are immediately accessible everywhere in the world but may easily be revised or erased by others. Finally, peer-reviewed articles in open-access journals have infinite reach as scientific learning objects. They also allow students to demonstrate disciplinary literacy and actively position themselves as authoritative practitioners in the field, which Rachel Riedner and colleagues (this collection) explain as necessary for promoting inclusion through professional identity formation.

Writing as the Ultimate Learning Object

Writing supports student learning across STEM curricula. First, writing is thinking. Necessarily, the process of writing involves planning, drafting, reading, and revision. As such, it requires thinking about the subject of writing as well as thinking about one's ideas on the subject in a non-linear and recursive manner (Hacker et al., 2009). That writing is thinking is also supported by the fact that metacognitive knowledge increases with writing skill, and both can be enhanced by pedagogical approaches emphasizing direct instruction on the metacognitive aspects of writing (Harris et al., 2010). Self-regulation, which involves goal setting, self-evaluation, and self-accommodation or help-seeking, is another key component of skilled writing (Harris et al., 2010). In this vein, Self-Regulated Strategy Development (SRSD) is an empirically supported pedagogical approach to facilitate the acquisition of effective writing strategies by providing students with knowledge of various writing tactics, supporting their self-management, and enhancing their motivation throughout the development process (Harris et al., 2010).

According to Karen R. Harris, Tanya Santangelo, and Steve Graham (2010), SRSD includes six instructional stages. In the first stage, the student develops and activates awareness of what is needed for good writing in a particular genre. This may be accomplished through exposure to examples of that literature with an eye on the declarative, procedural, and conditional elements therein. In the second stage, subjective aspects of writing, such as personal attitudes and beliefs about writing and the purpose and potential benefits of specific writing strategies to be learned, are discussed. In the third stage, the instructor models, for instance in collaboration with students, the constructive process of composition. A fourth phase involves memorization of certain mnemonics related to writing. More importantly, the self-regulation of student writing is supported by various means in stage five, culminating in their independent self-regulation and performance of writing tasks in stage six. A parallel of this is the "integrated knowledge" model described by Kara Taczak and Liane Robertson (2017), where students combine the acquired awareness of writers and the writing process with understanding gained from experiences outside of the classroom. Importantly, this model recognizes the value in the diverse perspectives that students bring to learning and writing.

Second, adding to the premise that "writing is thinking," this further represents a means for apprenticeship. Through writing practice, students can adopt a disciplinary framework, acquiring skills for technical communication with other scientists. Despite the instructor's propensity to recruit and indoctrinate their pupils into her own discipline, it is important that the writing strategies we teach serve students in many settings. Thus, special attention should be paid to science writing for different purposes and through different modalities. Students of STEM should be able to transfer their acquired writing skills to achieve effective communication or translation of science through audio-visual presentations and various genres or modalities of writing (e.g., technical reports, white papers, op-eds, social media). Third, contrary to learning strategies like rote memorization, writing is a form of tool used in the behavioral ecological sense because the technique is observed, imitated, practiced, and reworked with increasing mastery. According to Ian McGilchrist (2019), the neurobiological phenomena that underpin our ability to grasp facts are akin to those that coordinate our ability to grasp the pen for communication through language. Thus, although typically conceived as a skill, writing is fundamentally a tool. As a tool, writing also facilitates the transmission of knowledge between individuals and groups, as well as across generations and time. It is in this final way that writing represents the ultimate learning object.

To curate high-quality, knowledge-based learning objects, the instructor must first consider factors influencing students' motivation for working on NDA "products." Instructors should give full advanced disclosure of ultimate use(s) for student work with an option to contribute shared work anonymously (opt out of public exposure). By extension, the instructor could consider offering "traditional" disposable assignment options (e.g., essays) of equivalent weight for students who are not inclined toward public service or engagement. The instructor must also recognize a need for extensive scaffolding (support), develop a means for the internal vetting (i.e., quality control) of student-sourced learning objects, and adoption of grade-based incentives to facilitate the production of high-quality materials. For example, requiring multiple drafts separated by peer-assessment and revision allows student work to keep pace with the course and improved by positive feedback while they exercise self-regulated learning. An additional benefit is double-blind peer assessment (in large courses where some degree of anonymity can be maintained), which may enhance knowledge gain and metacognition by exposing students to new information or ways of thinking.

One early adopter of non-disposable assignments, Rajiv Jhangiani (2015), observed significant creativity in what students brought to bear on their projects. For similar results, instructors should give latitude or flexibility to accommodate students' creativity and heterogeneity of resulting learning objects/products. For example, in his initial attempts to incorporate NDAs in undergraduate courses, Jhangiani (2015, 2017) began by encouraging projects aligned with program and course learning objectives. Requiring prior approval for student project ideas or offering students a limited range of projects that suit preexisting learning objectives may inevitably lead to empirically grounded solutions in the outcome of student work. Thus, principles of backward course design can be used as a preventative technique for failing NDAs. To increase the probability that high-quality learning objects will emerge from student NDAs, the instructor should model the creation process and show examples of NDAs achieved through best practices. Finally, it cannot hurt to review guidelines for open licensed publication (for true OER) or release (for assignments that are shared outside of the course, but not by definition OER, such as "letters-to-the editor") of student work. The evaluation of learning objects created by students through NDAs requires the development of hitherto non-existent, empirically based standards for their classification and associated metadata. This metadata would facilitate future reuse or adaptation of learning objects. In the meantime, one can develop personalized methods for rating (external quality control of) student-sourced materials, keeping in mind that consistency in student outcomes and convergent solutions will emerge from empirically grounded work.

Example Non-disposable Assignments Featuring Intensive and Multipurposed Writing in a Scaffolded Environment

In the spirit of open pedagogy and with the aim to equalize access to the STEM professions, I have implemented intensive scientific writing through NDAs. To illustrate how this could be incorporated into STEM courses, I offer specific examples from my Brain and Behavior course. Student writing serves multiple functions throughout the semester in this writing intensive course, which is required for second-year psychology and neuroscience majors. What follows is a detailed description of some NDAs as well as an overview of the method by which I have incorporated a focus on writing in this and other STEM courses. The major assignment phases are illustrated in Figure 9.2.

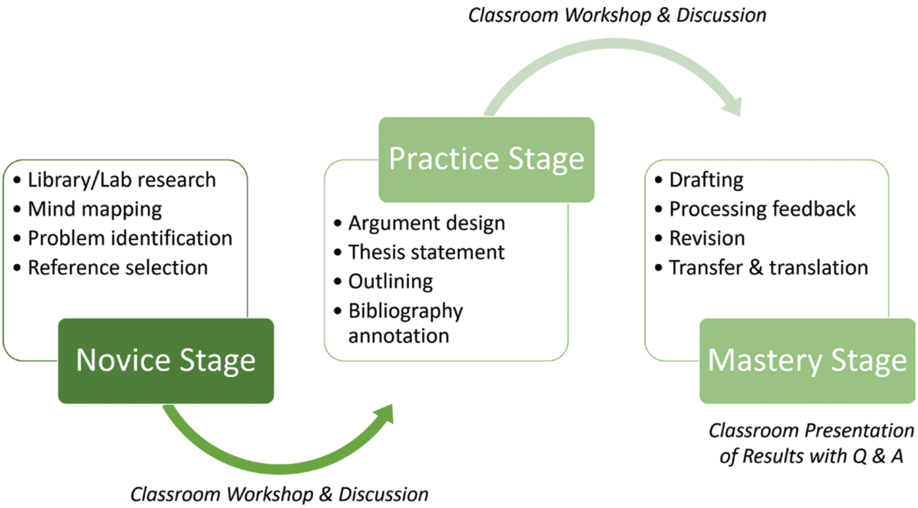

Figure 9.2: The three stages of STEM writing progression

Written NDA I: Writing as a Path to Establishing Healthy Classroom Norms

From the outset, themes of collaborative and inclusive writing are invoked when we begin the semester with an activity where students help to write a portion of the course syllabus. On the first day of lecture, each student is asked to describe, in one sentence entered on a shared electronic document, the attributes or values that they would like to have epitomized in our classroom culture. This information is summarized in a word cloud (an infographic that gives visual prominence to higher-frequency words), which becomes embedded in the "Class Norms" section of our course syllabus. Individual participation makes up 5 percent of the course grade, and the participation rubric includes a section related to the student's adherence to and support of the collective norms established through this activity. This process of going from crowd-sourced information to a single infographic that serves as a semester-long learning object also foreshadows the ongoing production process for NDAs.

STEM Writing NDA II: Active Reading through Writing

Student writing should be used to support reading as a critical skill component of any college education (Klucevsek & Brungard, 2016). I address this through interconnected individual and group learning activities. We use a digital textbook that has a built-in notebook and journal, which invite students to summarize and reflect on their course readings through daily writing. Whether similarly accomplished with a physical textbook and note-taking, the act of paraphrasing course reading and personally relating important concepts through writing represents "active reading." This exercises individual metacognition and provides benefits for comprehension and retention of the information therein (Fisk & Hurst, 2003; Hirvela & Du, 2013). With "translanguaging," where multilingual students apply all their linguistic knowledge toward making sense of an assigned reading (Hungwe, 2019), this paraphrasing may equalize reading skills in traditionally marginalized students. Thus far, the notebook and journaling are ungraded and merely offered as an opportunity for study skill enhancement. This could easily be formalized as an individually graded component to maximize the incentives for improving literacy in STEM majors. In a connected learning activity culminating in shared learning objects, students can enhance their scientific literacy by collating what they and classmates identify as important information from the textbook while note-taking or journaling. Using a shared electronic document that I provide, groups of students are required to contribute written content to "fill in the blanks" on course exam guides containing only an initial list of keywords or phrases. Being crowd-sourced, this written NDA conserves individual studying effort by making light work of an otherwise labor-intensive task. In keeping with what Kristin M. Klucevsek and Allison B. Brungard (2016) described as the need for STEM domain-specific literacy, this written NDA may also level the learning playing field by exposing important information that may have been missed by students with less experience reading or deciphering discipline-specific text. By using their own words to fill in the study guide, students also model skills for scientific translation, effectively peer-teaching. The class comes to realize first-hand a benefit of the NDA.

STEM Writing NDA III: Moodle Discussion Forums

Students practice communicating their own perspective or analysis through regular asynchronous discussion forums maintained on Moodle, a course learning management system. These required Moodle forums comprise 10 percent of the final grade and involve a two-step process whereby students initially respond to a posted discussion prompt (e.g., a case study, video, news article related to that week's lecture topic). Next, they must comment on the responses of one or two peers, depending on the length of the multimedia prompt, for full credit. While I monitor the thread for adherence to class norms of conduct and may periodically inject additional resources for their consideration, I regard this as a predominantly student space devoted to their discovery through peer-peer interaction. Beyond allowing them an opportunity to practice short-form science writing as they hammer out controversies related to brain and behavior, the forums also represent a "Class Level" NDA because of the compulsory and visible inter-peer exchange of perspectives (here, the learning objects).

STEM Writing NDA IV: Semester Research Project

Two fundamental components linking all my courses are group research projects and intensive writing. Besides simulating the practical aspects of everyday science, these afford an opportunity for students to build upon or transfer previously acquired skills and integrate their curricular knowledge, which is key for inclusive STEM learning (Basu et al., 2017). In laboratory courses, groups of students produce highly technical writing in the form of lab reports. In lecture courses, students have more flexibility to communicate their ideas using a scientific framework through writing analytical or persuasive research papers. In both cases, the group element qualifies this form of writing as a "Class Level" NDA because students together plan, create, organize, refine, and combine individual subcomponents of the ensuing learning object, which may then be revised for resubmission. In a semester-long NDA comprising 12 percent of the course grade, Brain and Behavior students practice a sequential approach to written communication by completing several ungraded, low-stakes assignments or learning activities that build up to two final group research deliverables: a paper (9 percent) and a presentation (3 percent). Not long after the syllabus review and introductory lectures, the semester research projects are launched with a class conversation about which of the course topics covered particularly interest them. Students are invited to enter three areas of research interest into a shared Google document. I then identify relevant topics that will not be covered in detail and would complement the course before students are invited to sign up to research these topics in groups of three to five. The semester-long research projects then proceed through three successive stages: Novice, Practice, and Mastery. Each lasts approximately four weeks and includes ample opportunity for instructional guidance within as well as between stages.

To begin the "Novice Stage" of the STEM Writing NDA, students receive specialized instruction from a Science and Electronic Resources Librarian about best practices for conducting a literature review, tools for managing bibliographic data, and the American Psychological Association (APA) Style (see Figure 9.2 earlier). At this stage, it may be useful to map the chosen research topic. This can be accomplished by simply brainstorming with paper and pencil or using a sophisticated library resource such as CQ Researcher or Credo Reference: Academic Core, which graphically displays related concepts, issues, events, and pro/con information. With a mind map in hand, students can better choose their search terms and decide which rabbit holes to pursue as they probe scholarly literature databases for reference information. After determining their topic parameters, students are encouraged to identify a problem or question to guide their research. One week after the library workshop, groups submit an ungraded topic declaration form including a preliminary bibliography, paper title, presentation title, and three to four scholarly resources per person. The "Novice Stage" concludes with a whole class discussion about successes and problems encountered during the initial library research process. In this way, the separate experiences of each group become an example or "learning object" from which others can benefit.

In preparation for the "Practice Stage," a classroom workshop on the nuts and bolts of writing is held. First, students receive a list of resources outlining the basics of English grammar, how to paraphrase, when to use quotations, and how to avoid plagiarism. After discussing argument design around a thesis statement and the selective deployment of resources to explain a principle or present evidence, we review different strategies for creating outlines (e.g., chronological, topical) and annotated bibliographies. Students then have approximately three weeks to prepare a graded paper Outline and Annotated Bibliography assignment. The outline must identify which students will be responsible for each part (i.e., which questions or subtopics) of the overall paper. Annotations must include a sentence explanation about how each resource will be used to advance their argument. This last requirement forces students to be mindful about how sources help their product. It encourages them to be more selective and even consider substituting or supplementing their source material at this stage. Since the writing-thinking-rewriting process is part of what is being assessed with NDAs, there are minimal benefits for students using artificial intelligence (AI). Along with an interim grade (0-3 out of 3 points), the student groups receive very detailed feedback about their thesis statement, outline, and reference choices. We then devote class time to discuss overall trends observed in these early submissions so that all students can benefit from my observations. To emphasize the importance of a central theme, we also "workshop" their thesis statements. Notably, Jhangiani (2015) observed peer assessment of a quiz positively influences subsequent test scores in an introductory psychology course. In this vein, groups formally announce their semester-long research projects by sharing their prepared thesis statement. As a class, we discuss and troubleshoot the statements, clarifying the group writing goals in the process. Once each group addresses my feedback on their Outline and Annotated Bibliography, a completion grade of 3/3 typically replaces the interim grade.

As part of the Practice Stage, students begin the process of writing their first draft. In preparation for this, they receive a brief workshop on how to construct a paragraph from components of the approved outline. At this stage, students may be able to identify parts of the outline that lend themselves to topical, explanatory, and transitional sentences. They are also encouraged to rearrange elements of the outline for improved argument structure or paper flow. Each member is required to contribute 500-750 words, not including the bibliography, to an APA formatted group paper due at the end of this stage—approximately three weeks after the Outline and Annotated Bibliography. As an additional support, I encourage individual students or entire groups to meet with me as questions emerge while preparing this first draft.

The “Mastery Stage” begins with the submission of a first draft of group research papers for formal assessment. In addition to a grade, the student groups receive a detailed mark-up of their paper with individual-specific and group-level feedback. In my response to each group, I also include some overall remarks based on all the essays submitted in the class. This circumvents students committing new errors with subsequent drafts. Student groups are also encouraged to submit a copy of their paper and assignment instructions for review by the campus Writing Center staff. Ideally, once both forms of feedback have been received, we devote a small amount of class time to review and discuss next steps. After processing, collating, and organizing the feedback received, the student groups create and share their plan for revision over a series of weeks. I then work closely with individual students or groups needing extra support while implementing the necessary changes for achieving full credit on the final submission. The culmination of their semester-long STEM Writing NDA is a graded final draft that is due at the conclusion of the semester.

STEM Writing NDA V: Public Presentation of Semester Research Project

Continuing the “Mastery Stage” of the STEM Writing NDA, student groups prepare a 15-20 minute final presentation. This presentation is intended to introduce new information into the course content. I instruct student groups to craft the presentation around their thesis. Using a data-centered argument, they are advised to tactically deploy resources in a manner designed to persuade the class of their perspective. A draft presentation is due two weeks in advance of the final presentation deadline, and we discuss necessary changes. Finally, the last week of class is devoted solely to a symposium on their semester-long projects.

STEM Writing NDA: Student Feedback

Throughout the course, students had several small assignments to complete along the way. For example, topic choice, outline, preliminary bibliography, annotated bibliography, and first draft were all required before submitting a final draft and research presentation. At the course conclusion, 25 out of 30 students (83.33 percent) participated in an optional 4-question Moodle survey where they were asked to rate the statements in three questions according to the Likert scale (a. Strongly agree, b. Somewhat agree, c. Uncertain, d. Somewhat disagree, and e. Strongly disagree) with the ability to select multiple options. This was followed with a fourth short response question: “How has it been carrying out a semester-long research project? (Share anything you’d like me to know about your science communication journey).” These results are described in Table 9.1.

Table 9.1. Responses from Most Students on a Brief Questionnaire Demonstrated the Overall Success of Written NDAs.

STEM Writing NDA IV & V: Brain and Behavior Student Responses to an End-of-Term Course Evaluation Survey About the Semester-Long Research Project					
Q1: It was helpful to have multiple, low stakes assignments to shape my writing practice and the final research products (presentation, paper).					
Response Options	Strongly agree	Somewhat agree	Uncertain	Somewhat Disagree	Strongly disagree
Percent Chosen	76%	24%	0%	0%	0%
Q2. Interrogating the literature for a specific topic enhanced my learning of brain and behavior.					
Response Options	Strongly agree	Somewhat agree	Uncertain	Somewhat Disagree	Strongly disagree
Percent Chosen	45.15%	46.15%	7.69%	0%	0%
Q3. My semester-long experience of technical research and writing left me feeling more empowered, knowledgeable, or prepared for any future explorations of careers in STEM.					
Response Options	Strongly agree	Somewhat agree	Uncertain	Somewhat Disagree	Strongly disagree
Percent Chosen	46.15%	38.46%	11.53%	0%	3.84%

Among student respondents, 76 percent strongly agreed, and 24 percent somewhat agreed with the statement: "It was helpful to have multiple, low stakes assignments to shape my writing practice and the final research products (presentation, paper)." Among the 24 percent who "somewhat agreed," the following comments highlight the overall positive experience of working on these assignments, notwithstanding problems encountered by their individual groups:

> I think having the research project being completed in sections over the course of the semester was helpful in making it better quality.
>
> The semester-long research project was fun to have because we got to research a topic of our interest. Since it was a semester-long project, it was not as overwhelming as a normal project will have. In addition, it was a good idea to work in a group of 5 because we had the chance of getting to know each other.
>
> At first, it was a bit intimidating to hear about this semester-long research project. However, because it was divided into multiple parts, the process didn't feel overwhelming. Overall, I enjoyed

> the process of studying a specific scientific phenomenon and working with my classmates.

46.15 percent strongly agreed, 46.15 percent somewhat agreed, and 7.69 percent were uncertain about the statement, "Interrogating the literature for a specific topic enhanced my learning of brain and behavior." The following representative quotes were from students who strongly or somewhat agreed with this statement:

> I thought it was interesting to [focus] on a topic and a specific subset of that topic to be able to become an expert in that field. I felt as if this did enhance my learning of brain and behavior. . . .

> This was the first research paper I worked on in a [STEM] field explicitly, which I did actually enjoy. I was able to elaborate on my knowledge of schizophrenia in a psychological sense and expand on [its neuroscientific bases *[sic]*]. . . .

> I think that it was very interesting to carry out a semester-long research project because I was able to connect each topic that I learned in class to what my research project was based on. This enabled me to gain a greater understanding of both the course material, and my research. Understanding the fundamentals of neuroscience throughout the course helped me to communicate in a scientific way that was focused [on Post Traumatic Stress Disorder]. I think that applying this knowledge is a skill that I will continue to use in my scientific writing.

When asked to evaluate the statement "My semester-long experience of technical research and writing left me feeling more empowered, knowledgeable, or prepared for any future explorations or career in STEM," 46.15 percent strongly agreed, 38.46 percent somewhat agreed, 11.53 percent were uncertain, and 3.84 percent strongly disagreed. Three students who reported uncertainty about this added:

> I like the idea of a semester long research project. I liked the ability to choose topics. However, I wish the groups were smaller. At times I felt that people had clashing ideas for the project and what we wanted to focus on. It was also hard to write a paper and try to get 5 people in the same place at once due to conflicting schedules.

> Carrying out a semester long research project in the background of weekly quizzes, weekly Pearson assignments, recorded lectures, forums, and exams was far from ideal. Although the premise of a research project enhancing our scientific reasoning and writing was well-intended…

> I felt that the process would have been quite interesting, but I felt that the communication / organization between group members made the process quite stressful and disorganized… I felt that if there were an established platform for communication between group member, group planning and working would have [gone] more smoothly. However, [it] was fulfilling to have a side project / interest during this course.

A student who chose both options "strongly agree" and "strongly disagree" for statement #3 said:

> I really liked having a semester long research project. I think that it allowed me to become closer with people in the class who I wouldn't have otherwise and thy was useful when trying to study or putting faces to names in the discussion forums. I also think these projects were very useful to develop my ability to write scientific papers and prepare my research to be presented. I'm a biology major, so I will definitely have to do more papers like this in the future, so having the opportunity to work together for the whole semester with check-ins along the way made it really easy to get it done. The feedback from my group mates, Professor Seraphin, and the [Trinity College] writing center allowed me to go back and edit my writing in a way that would allow me to [perform] better on the next paper that I write.

The following comments were made by a large number of students who chose "strongly agree" across the board:

> I thought that the semester-long project was extremely valuable in that I learned so much about how to properly research, source, and write literature pertaining to the topic of substance abuse. Being able to engage with the material over the entire semester allowed for my understanding to deepen as [I] continually got to engage with the material in different forms. . . .

> I think it was a good way to learn about neuroscience in a new way. Our class was so fast paced and lecture heavy, that having a chance to research something on our own was very helpful. I think it was a good way to meet other peers as well!

> I really liked having it be a semester long because it allowed me to learn and take my time without an additional stress to make a final paper in a week. I also was able to connect with classmates

> and discuss class topics and work. [Although I was extremely nervous,] I felt accomplished that I was able to present my work.
>
> I feel the semester-long research project was quite fun. I found it enjoyable to learn more about a specific aspect of brain and behavior and then share what I learned with the class. I also found it valuable to learn how to work in a group. Developing communication skills and the ability to work as a whole rather than separate parts was a good learning experience.
>
> I liked doing this project even though it was more challenging to write a group paper compared to working independently. It was extremely helpful for the course overall to have a group of peers that I could talk to.
>
> It was very helpful to have had multiple assignments for this semester long research project, as it provided a lot of feedback to help my group work on aspects of the paper (for example) in addition to allowing us to have a lot of time to not only grasp the material deeply but also to enhance our interests in the topics by exploring literature and research conducted about them.
>
> I really enjoyed having a semester long research project, I think one of the main reasons why I enjoyed it so much is because we were able to turn in small portions of the assignment as we went along. [N]ot having to turn in the full project at a specific due date alleviated a lot of stress and allowed for me to plan ahead and produce my best work.
>
> [I] thought it was very helpful to have a structured plan in doing this project especially considering it was done in a group. [Also I] think that the lecture time we spent talking to the library research staff was really helping in finding informational and credible sources. [H]aving Professor Seraphin check and give feedback on our work was really helpful in guiding us in the right direction. [T]he mandatory writing center appointment was also a good way to have our papers checked. [Overall, I] think the whole process was great and very helpful in completing this project.

Students and instructors can be resistant to the adoption of NDAs. Despite potential benefits, student reluctance to engage in group work represents an obstacle for implementing group NDAs. One barrier to working in collaboration is the unequal effort and different costs incurred by group members (Terras et al., 2013). For example, social loafing within a group can discourage sharing among the more conscientious students demonstrating progress on group NDAs. While most groups in my course managed to work together very well by the end of the semester, there were one or two situations, largely exacerbated by student illness, where things remained shaky. In this regard, one student wrote:

> It has been an interesting experience carrying out a semester long research project. I think one thing that stands out is that through this project I was able to work with a diverse group of people and we had to really learn how to work efficiently together. I think this is a great experience as group work does not end in the real world. We had to step up and be leaders and each play a role which was sometimes difficult to navigate.

Written Non-disposable Assignments Represent a Means for Diversifying STEM

We should address inequities in STEM through the adoption of written NDAs because they subvert the structures that reinforce hegemony. We should also embrace them as a means for greater equity because of their ability to enhance learning. Students may struggle to find the purpose or meaning in traditional assignments, which they not only experience as rote and mundane but are tiresome to grade (Jhangiani, 2015). According to Allan and colleagues (2018), well-being and productivity can be enhanced by doing work that benefits people other than yourself. In a study of students, working adults, and public university employees, it was found that people who do work to benefit others experience greater task meaningfulness and increased work meaningfulness over time (Allan et al., 2018).

As knowledge workers, future students will ‘think for a living’ (Fontana et al., 2015). Thus, a soft skill educators should impart on students is self-regulated learning (SRL), or the ability to assume responsibility for one’s professional development by self-regulating one’s personal learning needs in an increasingly knowledge-intensive workforce (Fontana et al., 2015). NDAs enhance SRL by simulating the process by which future workers must gain and manifest expertise in a supportive educational environment.

NDAs offer instructors the opportunity to increase students’ self-efficacy as they target the development of three general motivational beliefs (Pintrich, 1999 & 2000), including self-efficacy beliefs, task value beliefs, and goal orientations. According to Albert Bandura (2002), self-efficacy not only supports our potential for success and feelings of well-being in a variety of life situations but also impacts the development of media literacy skills. This is particularly important as academic achievement and media literacy are becoming increasingly linked (Terras et al., 2013). Higher-order media literacy skills are needed to push student learning horizons beyond the old limitations of time and space (Terras et al., 2013). To optimize the learning potential of OER, instructors must attend to the psychological dimensions of media literacy skills in their students. Many cognitive (e.g., student's cognitive load, mental representation of internet searches, recall of linear versus non-linear websites, pairing of learning goals with navigational skills), developmental (age), and psycho-social factors (introversion-extroversion, meta-cognition, self-regulation, self-efficacy, self-esteem, and motivation) influence e-Learning by enhancing or impairing the acquisition or maintenance of media literacy skills (Terras et al., 2013). Metacognition is marked by the ability to evaluate, regulate, and monitor what one knows. The effective learner is not only aware of their knowledge but can recognize learning and speak to their learning process as this unfolds (Terras et al., 2013). By scaffolding stages of completion in NDAs, we train student's metacognitive ability while stimulating the three critical phases of self-regulation (Zimmerman, 2002): forethought, performance, and self-reflection.

As they write for different purposes, my students develop media literacy through discussion forums and the creation of audio-visual components for their final research presentations. Using NDAs can help level the playing field for students from underrepresented groups. While those with developmental exposure, through gaming, etc., can easily transfer this experience to the educational task at hand, others having less ease with technology may struggle to meet the competing demands of two separate academic challenges: the learning activity and the technology (Terras et al., 2013). Prior life experience with technology can limit the potential for achievement in using and generating OER because this is associated with different cognitive profiles (Terras et al., 2013), possibly via enhanced visual-spatial skills and lower higher-order processing skills as observed in video game players compared with non-games players (Green & Bavelier, 2006). Eszter Hargittai and Gina Walejko (2008) observed a reduction in typical gender differences, for sharing on social media once internet user skill was controlled. Thus, as psychological enablers, NDAs represent an opportunity for instructors to impact development of a highly demanded vocational skill (i.e., media literacy) typically associated with relatively fixed characteristics such as socioeconomic status (Hargittai & Walejko, 2008), educational opportunity, or age (Terras et al., 2013). By lessening barriers to participation through open pedagogical practices that foster media literacy, the instructor could equalize the playing field for students from underrepresented groups. If other identifying student features (e.g., race, gender, ability, etc.) remain constant, we would thus expect to observe greater richness in the learning objects generated by a more inclusive and now diverse body of STEM practitioners.

Why address inequities in STEM through the adoption of written NDAs? My personal answer to this question is informed by my positionality as a Black female teacher-scholar with personal hindsight and deep aspiration for change. First, while reflecting on how I have felt enabled, writing emerged as a particular source of confidence that kept me grounded in the pursuit of education. My writing journey probably started in high school, where I excelled in Advanced Placement English, but my sense of being a good writer was instilled during a brief college experience at a historically Black institution, Howard University. In keeping with my initial identification as a pre-med major, I chose to enroll in a technical writing course to satisfy the English composition requirement. By mechanisms I cannot now recall, I was therein endowed with the knowledge of how to decipher and produce writing in the manner typical of science communication. I learned not only to decipher but also to adopt jargon as a second language. I came to embrace the rhythmic structure used for reporting empirical research as a stable, orienting device. In a History of the Black Diaspora course intended to fulfill the humanities requirement, I explored my Haitian ancestry through an ethnographic research paper that allowed me to experiment with writing infused with my personal voice. These two intensive writing experiences left me feeling capable and competent in writing for various purposes. Long after I had transferred from Howard to the University of Massachusetts-Boston, where I ultimately earned my bachelor's degree as a commuting student, I observed writing to be the way I could effectively signal my accumulating mastery of scientific concepts and principles—even when momentary changes in my work schedule or family demands periodically prevented top performance on quizzes requiring rote memorization. Eventually, it was my writing—and especially the innovative thinking that it revealed—which stood out, earning me admission to graduate school after a less-than-stellar undergraduate record. While studying human biology at Oxford University, I composed essays in preparation for weekly individual or group tutorials. This experience demonstrated to me that writing is not only a means for communication but also a device for thinking. The confidence I developed in writing helped me to distinguish between writer's block, where emotions interfere with my productivity, and writing difficulty rooted in technical problems around preparation, focus, or confusion about the process. Eventually, my comfort with writing made completing my thesis less daunting.

Second, as the child of immigrants, the plight of poor and marginalized communities within and outside of the academy particularly resonates with me. While advocating for institutional, infrastructural changes to help retain minority students in STEM at the colleges where I have worked, I realized that my underrepresented minority neuroscience students are educated in a STEM context that is predominantly white, cis-gender, affluent, and also views itself as the gatekeeper for future opportunities in research and clinical practice. Although technically a part of the academy, they are tacitly maintained as separate and divided in a way that surely impacts their ability to learn and thrive in the disciplines. Over many years of teaching anthropology, biology, and psychology to class sizes of 1 to 300 students at small liberal arts colleges and large public or private universities, I have also recognized that behavioral sciences education presents special opportunities for an educator to engage students on the bio-cultural bases of human experience and its implication for important social issues, such as racial and economic health disparities. I also noticed the second tension—that between town and gown, or people who pay tuition and Others in their surroundings who are denied access to that commodified knowledge. In addition to advocating for minority students within the college walls, this inspired an interest in open pedagogy, which has the effect of enhancing the equitable dispersal of information—through the pedagogical innovation of NDAs for STEM teaching. There are endless possibilities for fostering gains in social justice (Bali et al., 2020), diversity, equity, and inclusion in STEM by sharpening the tool of writing through NDAs. In other words: Putting STEM in black and white.

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