First Year Writing for STEM Students: Promoting Awareness between Writing and Science

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Often, composition instructors struggle to encourage STEM (science, technology, engineering, and math) students to see the relevance of writing courses to their personal goals. Students' lack of recognition of the importance of literacy skills can lead to disengagement in required college writing courses compared to their so-called "hard" science courses, and, ironically, hinder their future academic and professional success in STEM fields. The first year writing (FYW) course we introduce, LB 133: Inquiry in Science & Society through Writing, was designed for students at Lyman Briggs College, a residential college for the sciences at Michigan State University, with the goal of engaging and empowering the students in writing through inquiry-based projects on the relationship between science and society. Iteratively and collaboratively developed and taught, the faculty teaching team—led by the lead author—has worked from a common syllabus, sharing activities and assessment tools. Each element of the collaborative course is designed to promote writing skills and, in particular, critical science literacy, the ability to meaningfully read and write about science. [1]

Institutional Context

Lyman Briggs College (LBC) is a residential college located within Michigan State University that aims to provide an inclusive, high-quality science education to diverse students. Unlike many traditional science programs, the college is founded on what Anne Fausto-Sterling calls an interdisciplinary understanding of science in context. As of 2020, the college's mission statement is:

> Lyman Briggs College is a residential, undergraduate, science-focused learning community dedicated to innovative and inclusive teaching, research, and engagement with the sciences in their diverse human, social, and global contexts.

In keeping with the college mission, students are required to take several science and society courses that also fulfill their Tier I and Tier II writing requirements. At LBC, about 80% of the roughly six hundred incoming students who do not test out with AP credit enroll in a twenty-four-person-capped section of LB 133 in their first year. A significant majority of these

students are life sciences majors, with most intending to pursue a pre-medical track, distantly followed by those interested in environmental science. LB 133 is situated as both the student's university-required Tier I (first year) writing course, limited to LBC students, as well as an introduction to critical interdisciplinary approaches (e.g., historical, philosophical, and sociological) to science and society.

LB 133 provides a unique opportunity to cultivate an understanding of the significance of writing for STEM students. For example, Maria E. Gigante reports that most major universities do not require courses that engage students in cultures of writing in scientific disciplines, even at highly ranked STEM programs that emphasize communication skills (78). The lead author and her collaborators at LBC saw this as a problem. Not only do students need competent academic writing skills, but also learning how to write encourages students to be critical thinkers aware of how knowledge is produced. With this awareness, LB 133 takes writing as a cultural artifact and a practice that embodies knowledge. It introduces science as a discourse layered with cultural, social, and human context through various writing practices instead of ostensibly a set of cold objective facts about nature. As such, the writing component is not a simple means to achieve this understanding. Rather, writing about science as a cultural practice is both the means and the goal of this course. By the end of the course, students are expected to exhibit various academic writing skills and demonstrate their understanding that writing is a cultural and knowledge-production activity. In seeking to fulfill this dual role, the course is composed of five writing projects that engage the students in modes of inquiry into the relationship between science and society.

LB 133 has been part of the college curriculum since at least 1997 and has taken many forms since. In 2017, the lead author was tasked by the college with establishing common learning goals for the course as a whole to be shared across sections. One goal of this effort was making writing explicitly relevant to STEM students. It had become apparent that students were influenced by the idea that writing was not relevant for science-based professions, and thus lacked motivation in writing courses. Moreover, studies have indicated that students expect "applicability and practicality" (Heaser and Thoune 112-13) in FYW courses and often lack motivation when they do not see how the topics emphasized in FYW classes such as rhetorical choices and compositional skills influence "their day-to-day actions of writing" (Heaser and Thoune 113). Disengagement with writing can further undercut a student's sense of belonging and success in science as well as in college. Previous studies have shown that students who receive a C or lower in their first year writing class have a 17% chance of graduation and that failing an FYW course has roughly the same consequence for a student as failing a major-related class (Garrett et al. 96).

Recognizing this problem as well as the importance of writing, LBC launched a redesign of the first year writing course that is designed to make the connection between writing and science explicit. Over the course of more than a year of active curriculum development efforts, in addition to continuing revisions now entering their sixth year at the time of the writing, the lead author and several of her Science & Society colleagues arrived at a novel synthesis. They developed shared learning goals that target critical literacy about science and a set of writing projects that align the learning objectives with each project. These learning objectives and writing projects are detailed below.

Instructional Goals

Our course operates on the premise that writing is an integral part of scientific cultures (Otfinowski and Silva-Opps 22; Seraphin 13). Targeting first year STEM students specifically, the course has two major sets of learning goals: one set tied to knowledge and the other to skills.

First, it aims to empower students by promoting a critical understanding of science as culture through writing. Writing is a necessary skill for developing scientific literacy as it promotes reflexivity about what one knows and believes in the given context, which is associated with the understanding of scientific knowledge as a culturally and historically situated enterprise (Seraphin 13). Opportunities to receive formal writing instruction at science colleges, however, are often limited to lab reports, expecting students to follow the sequence, typically introduction, methods, results, and discussion (Oliveira 1210). Also, writing courses tend to focus on sentence-level syntax and citation formats (Otfinowski and Silva-Opps 19). Despite the importance of the academic format, those approaches to writing at an early stage of learning can be problematic. The formats and fragmented sections of lab reports, for example, can reinforce students to fit their learning into the given format first, inhibiting them from synthesizing their learning; ultimately, it runs the risk of students misunderstanding scientific research as a linear process (Oliveira 1210). We encourage students to develop a critical understanding of the human and social dimensions of scientific knowledge by having them read and write about science as a social institution and practice and by having them imagine their audience as non-scientists. This understanding of science promotes not only views of justice and equity, but also their own agency in science learning (Schenkel et al. 312).

Second, this course seeks to promote writing as a rhetorical practice that helps students learn how to effectively communicate their understanding of their disciplinary cultures to others and to themselves (Hyland 9). More specifically, we look to develop students' writing as a communication skill, which entails identifying needed information, connecting ideas, developing a

writing style in accordance with audiences, and honing the ability to employ the metacognitive process of looking at an issue.

To achieve these goals, the course adopts a pedagogical strategy that combines reflective writing with inquiry-based collaborative projects. Throughout the course, students learn how to investigate, evaluate, and write about scientific claims. Particularly, students study how scientific knowledge is made and circulates, communicate that learning through writing, and reflect on how their newly acquired rhetorical practices and critical viewpoints will impact their individual journey through science. The course leads students through five scaffolded projects that utilize multiple forms of writing to develop a critical understanding of science as culture: a personal statement, a portfolio report on a professional scientific site, a fact-checking project, a website exploring a socioscientific issue, and an addressed letter. The alignment between the assessments, their science and society knowledge learning goals, and their writing and literacy learning goals can be seen in Table 1.

Table 1

A brief summary of the five writing projects with knowledge (content) learning goals and writing skill learning goals

Assessment	Science and Society Content Learning Goals	Literacy and Writing Skills Learning Goals
Part 1 - Cultures of Science		
Personal Writing 1: Personal Statement Short form writing from scientific subject position	Reflect on evolving identity, role, and responsibilities in scientific culture	Diagnostic for answering questions, supporting a claim, providing evidence, structure, and clear writing
Scientific Sites Portfolio Collaborative investigation of how a local lab produces knowledge	Understand scientific practice, reasoning, and communication in its diverse social, material and cultural contexts. Demystify labs and humanize scientists.	Making observational field notes. Reading scientific papers. Peer review. Writing analytical essays based on observation.
Part 2 - Science in Culture		
Trace that claim! Partner project assessing validity of a public scientific claim.	Understand the mediation of science and how to evaluate scientific claims. Identify popular conceptions of science and contrast these with scientists' practices.	Following sources upstream. Comparin sources. APA citation style. Visual display of information on a poster.
Perspectives Portfolio Collaborative investigation of a debate concerning science in Michigan.	Identifiy and analyze how diverse stakeholders are included in and/or excluded from science. Recognize the value of diverse perspectives.	Find, use, and correctly cite primary and scholarly secondary sources from different stakeholder perspectives, Websites.
Personal Writing 2: Letter and Course Reflection Sharing a course takeaway with someone.	Reflect on evolving identity, role, and responsibilities in scientific culture.	Final assessment of answering questions, supporting a claim, providing evidence, structure, and clear writing.
Weekly Formative Assessments		
Discussion Activities Pre-meeting writing about the readings	Reflect on prompted aspects of science and culture	Writing as critical inquiry, note-taking, and preparation for discussion.

Theoretical Rationale

Critical Science Literacy

The design of this course was, in part, inspired by scholarship on teaching practices that seeks to develop critical science literacy. The works of Susanna Priest, Maria E. Gigante, and Sara Giordano have initiated serious conversations about why writing is important for STEM or science students and exactly how to integrate writing or composition with science education. For instance, Priest, a science communication scholar, advocates that understanding how science works as a social institution is essential for evaluating scientific claims. In a similar vein, Giordano draws upon feminist science studies and conceptualizes reading and writing about science as students' experience with understanding science as a knowledge production. Moving one step further, Gigante argues that writing classes can go "above and beyond exposing how things work in the sciences to include a 'production," or communication component, so that students can become responsible and effective communicators in their future careers" (78). Learning various techniques for writing for different audiences, contexts, and purposes sensitizes students to those rhetorical aspects of an argument, thereby training them to not only analyze and evaluate texts effectively but also practice their own production of argument. Moreover, Gigante argues that this rhetorical training exposes students to "the moral concerns that arise in various situations" in sciences or scientific situations ultimately developing "critically literate" citizens to improve democracy (79). As such, this scholarship shares the goal of promoting critical science literacy to bring awareness that the scientific and technical fields are not separate from the humanities or the literary and to instill a sense of responsibility for effective writing in future scientists.

Many students enter science colleges viewing science as a collection of so-called facts objectively created through the scientific methods. The idea of science being free from biases and cultural factors can hinder opportunities to consider the humanistic and rhetorical implications of science and its societal impact. Thus, at the beginning of the class, students often report apprehension about the writing course or view it as superficial. However, when they start to see the interconnectedness of science, the social aspect of science, and scientists' human activity, they are motivated to take writing more seriously.

LB 133 uses writing assignments to promote critical science literacy by having students uncover the way scientific knowledge is made and how diverse perspectives are reflected through it. For instance, in the Trace that Claim project (which is similar to an assignment described by Giordano in 2017), students select a scientific claim circulating in popular culture, such as a news headline about a recent study or a health product advertisement on social media. After learning about how to use academic search engines with the

college librarian, students attempt to trace the claim to determine if it is based on a scientific source. In the assignment, students examine which stakeholders are implicated by the study and whether there is consensus in science literature. Ultimately, students realized that the so-called factual sciences are, in fact, situated knowledge claims. From a writing pedagogy perspective, students learn various rhetorical skills such as considering audience and context and finding and using different kinds of evidentiary sources, which also requires them to become more aware of how different sources reflect different perspectives.

To communicate what they have learned about the scientific basis for the claim, the team creates a multimedia writing project—such as a poster or brochure—designed to reach a specific audience they have identified as interested in the claim. This project allows students to understand how what we perceive as unproblematically scientific, and thus objective, is actually a claim, an argument made by socially-situated human activity.

FYW Projects Using Inquiry-Based Learning

The other framework of LB 133 is inquiry-based learning. Responding to the paradigm shift in higher education in the 1990s that reconceptualized learning as an individual process of constructing knowledge rather than receiving information (Fanghanel 61), inquiry-based learning acknowledges students as agents and not passive recipients in learning.

Speaking broadly of learning, Heather Banchi and Randy Bell argue that there are four levels of inquiry: confirmation, structured, guided, and open (26). Those can be described as:

- In confirmation inquiry, students are asked to "fact check" information.
- In structured inquiry, students follow a series of inquiry steps. The first two stages are rather rudimentary in that the instructor develops both the question and the procedure.
- The third level, guided inquiry, allows students to explore ways to investigate the question presented by the instructor, but asks students to develop inquiry processes. Here, students take a more active role in the research process.
- The highest level of inquiry-based learning is called open inquiry where a series of inquiries that require higher-level thinking on the part of a student is desired. At this level, students do not simply find solutions and select needed materials, but also identify a problem they want to investigate.

The ultimate goal of science literacy is deeply related to higher-level inquiry-based learning; both require students' autonomy in identifying a problem and collecting data and stretch beyond simply finding solutions to a given question.

All projects for the course entail an inquiry-based learning model and target the highest levels of inquiry-based learning to promote critical (science) literacy through writing. For example, the largest project of the semester, the Perspectives Portfolio, requires students to perform diverse inquiry methods. In this project, the students practice open inquiry by choosing a socioscientific issue and making a website that explores different stakeholders' perspectives. Past topics have included how schools should care for the mental health of students, how certain invasive species should be managed, whether marijuana should be widely available, or who should be held accountable for the Flint Water Crisis.

To analyze these perspectives, the students employ structured inquiry to create an annotated bibliography as a key step in their inquiry process. Through this process, students reflect upon how to effectively use different kinds of sources to write about science and learn the critical motivation of the writing. Each student writes an essay explaining a specific stakeholder perspective on the issue based on a combination of primary and scholarly sources and format it as a page on the website. Further building on their library search skills, each student is given inquiry steps that encourage them to identify and summarize two high-quality sources to help them understand the stakeholder perspective.

The students then utilize a series of guided inquiry steps that they have practiced in previous, formative writing assignments regarding rhetorical components such as audience and context and how they influence overall the writing style and argument. Students write individual essays about their stakeholders using their sources. Then, they work as a team to create an introduction to the website that explains the socioscientific issue they have chosen, summarizing and arguing for the value of each of the stakeholder perspectives and synthesizing what they have learned into an overarching argument about the nature of the controversy.

Although this assignment does not explicitly pursue an entirely open inquiry level in that there are specific requirements they must meet, it provides students with the necessary tools to perform an open inquiry later in their academic careers. Through such projects that target the highest levels of inquiry-based learning, this course uses writing to promote a critical perspective on science and academic writing skills. Students learn how scientific knowledge travels through writing, the different perspectives embedded therein, as well as its rhetorical importance.

Critical Reflection

Starting in the Fall of 2019, the team began collecting data from students to assess the success of this new LB 133 curriculum design. This IRB-approved data is composed of two surveys and a set of five reflection papers. At both

midterm and end of the semester, students take a survey and answer a series of short essay questions about what they have learned and which aspects of the course facilitated that learning. The intake survey now has responses from 308 students, and the post-survey has 113 responses. Additionally, students write a final course reflection (part of Personal Writing 2) that reflects on their progress over the course of the semester. Students answer several prompt questions that ask them to detail what they gained from the course in terms of specific writing skills, understanding of science and society, their sense of belonging in science and the college, and most impactful features of the course that helped them develop each of these. The authors have analyzed a total of 171 students' final reflection papers (55 from Spring 2021 and 116 from Fall 2020) to assess the success of this course design and identify patterns. These have provided valuable data about student experiences and learning for the instructors to reflect upon. We have selected several student quotes and statistics that underscore what we see as underscoring the achievements and challenges of LB 133 below.

Overall, students report finding writing surprisingly enjoyable and educational. Many felt motivated to write about science and saw rhetoric and writing skills as valuable to their career and field. Students demonstrate a positive response to this course, especially regarding 1) their recognition of their own positionality as writers and how this relates to the diverse perspectives of audiences, 2) their confidence and awareness of how to use writing to effectively reach audiences, and 3) the relevance of writing for attaining their personal goals in STEM.

Recognition of Diverse Perspectives on Science

We found encouraging evidence that suggests the course helps students appreciate the diversity of perspectives on scientific knowledge, including their own. By being asked to account for the various rhetorical and compositional elements of their writing projects in their cover letters—including, audience, purpose, and context—students reflect on how scientific knowledge travels through writing. Engaging with these rhetorical elements helps students to understand scientific facts as written arguments made up of claims and supporting evidence that embody a perspective. Not only does this process help students develop the skills to write with a rhetorical consciousness, but it also encourages them to recognize the humanistic aspects of science, or what students refer to as the "perspective," "culture," or "communication" when prompted by instructors. This is what the team has found most rewarding: students' developing awareness of their own positionality in science and how their rhetorical choices in writing projects can affect their ability to communicate with diverse audiences.

The following three quotes, taken from final reflections, show that students' newfound value of writing leads to a recognition and appreciation of both their own positionality and that of their audiences:

> . . . now I can see that there is so much more to being a science professional than just being book smart. People need to be able to understand perspectives in order to have a good understanding of any scientific issue. People need to be able to understand the difference between people and cultures . . . And overall, it [the awareness of culture and difference] makes people better scientists.

> To be honest I think the most impactful thing was learning about how science is built on trust and communication. Yes, I always knew that what you hear on the internet or TV is not always true. However, this class took it a step further and made me realize so much more. I never knew how much cultures had impacted someone's view until this class. I have social norms that I am surrounded by and other people have other norms that they are surrounded by. I never really put the two together to realize that we may trust different things and we both could communicate different scientific facts that we believe in. And the most crazy part is neither of us can actually prove what we are saying is true but only prove that it is false. I think that is a very cool concept to understand and also how we can shape how science is perceived.

> From writing so much I learned how to better portray specific information for the use of different audiences. Everyone has a different set of perspectives and scientific communication doesn't currently cater to most of them. While interpreting information I learned how important it is to not only gain a full understanding but to also be able to portray that information to different groups.

The students each describe how this writing course helped them to understand that various perspectives are central to the production of science. Actively reflecting on the "two cultures" (scientific and literary), the students comment that perspectives and personal or cultural values inherently exist in any scientific issue. As seen in these reflections, we have also noticed that many students tend to write in a more activist tone at the end of the semester that acknowledges their own responsibility to become better science communicators to engage diverse publics with what they feel they need to know about science. The instructors believe that this awareness and attitude would not have come without students learning to read and write about scientific

issues with specific consideration to various rhetorical elements such as audience, the way an argument is made, and style.

Confidence and Rhetorical Consciousness

One area of improvement we see across the board is confidence in and an awareness of their own writing abilities. In addition to most students reporting that their writing skills improved (92.6% based on the 133 responses in the Fall 2019 and Spring 2020 post-course survey), many students' responses display that they have developed a level of metacognition about their own writing and are better able to use writing intentionally for different purposes. For example, students reported the value of rhetorical skills such as defining key terms, avoiding unnecessary jargon, breaking down ideas into digestible paragraphs, drawing on relevant sources to support their claims, and recognizing the interests of their audiences. We believe this was achieved by students' experience with creating various forms of writing throughout the semester—a personal statement, a portfolio report, a multimedia research paper, and an addressed letter—which allow them to learn how to target specific audiences through different formats, and writing cover letters through which they reflected on how they worked to meet their goals.

Moreover, at the end of the course, students show more awareness of what is entailed in high quality writing and how to engage a process to create it. In the intake survey, when asked, "What is the main aspect of your writing that you know you would like to improve?," many students mentioned grammar and vocabulary as their weaknesses. This speaks to what they view as important in composition, that is, creating prose that reflects their stereotypes of how to appear intelligent to others by using stylistic elements students call "correct grammar" and "big words." In contrast, students' answers to this question at the end of semester showed a shift towards recognizing more foundational elements of composition and rhetoric. Students noted writing clear thesis statements, using evidence effectively, and creating structure and flow, in addition to grammar and word choice, as key skills they had improved on and wanted to continue developing.

Many students refer to "writing as a process" with many drafts and revisions as part of their writing skill set development. We saw students reflecting on their past experiences with turning in the first draft and how their writing process changed drastically throughout the course of the semester as they began to develop a more sophisticated process. For example, as one student wrote in a cover letter on their final writing project, a personal letter:

> From the many reflections, discussion posts and essays, I was able to learn the power of a first draft. Once I was able to get all of my

> ideas onto the document, there is so much editing, revising, and peer reviewing that I can do to convey my thoughts effectively. As long as I could put all of my ideas down and throw them onto the paper, it made my ideas so much more clear and effective in my mind and in class. Through peer review, those rough ideas were able to be refined into concise ideas and flowing sentences so that I was able to turn in the best possible essay that conveyed my ideas in the most effective way.

As a general trend, with each subsequent paper, students' cover letters evidenced more efforts to incorporate process skills including brainstorming, outlining, seeking out models, participating in meaningful peer review, and revising their prose for clarity and conciseness. Students also mentioned skills such as revisiting the prompt to ensure their writing stayed relevant and focused throughout this process.

Relevance of Writing

One apparent strength of the course is that most students report finding personal value in the writing content as part of their development as STEM professionals in training. This course was designed to make explicit the importance of writing for science, and our data suggests our approach was successful at reaching students across a range of interests and skill levels. When asked, "What do you think was the most important college writing skill or practice you learned this semester?," we find a wide variety of responses, suggesting that the course is meeting a diverse range of student writing needs and interests. Some students find foundational writing skills like forming a thesis and explaining evidence most useful; others focus on inquiry skills, like taking field notes or learning how to fact-check using scholarly sources; some emphasize the personal value of demystifying scientific cultures of writing, including the skills entailed in reading scientific articles and understanding the scientific publication process; and others write that learning rhetorical skills to communicate scientific issues to non-scientist audiences was crucial. The reflection written at the end of the semester also shows clear signs of students changing their perspective on the importance of writing. For example, one student reflected how they had "never fully understood that writing is an integral part of science. But, now, I realize that using writing skills is how I am able to outline certain objectives, communicate with other collaborators, and share science beyond academia."

We also gained insight into students' awareness of the importance of writing, somewhat unexpectedly, from a reflection question asking students what they would like to learn more about in the future. About 15.5% of the

students (18 out of 116 responses; Fall 2020) specifically mentioned wanting to learn more about various aspects of writing and do a deeper dive-in into the relationship between science and writing. From wanting to learn "specific writing styles [that] may be considered more trustworthy" and "how to write scientific research papers that get published" to "being able to better share that knowledge with a wide spread audience [by learning] how to transfer what I have learned about writing engaging pieces [. . .] that can both educate and hold the attention of audiences of all ages," students show a motivation to learn various rhetorical skills and an appreciation of the importance of writing in the fields of STEM.

Challenges

This course was developed as a response to the challenge of engaging scientists in writing training. But we recognize that the solution presented here is ambitious. This course includes five writing projects, each utilizing a wide range of practices, including scaffolded design, peer review, collaborative activities, and inquiry tools into the real world of scientific culture to help students write about science competently and from a culturally-responsive perspective. The biggest challenge of the course is to balance all of this within a four-credit, single semester course with up to twenty-four students per section.

For instance, the team had to revise the Scientific Sites Project to reduce the stress of completing several complex assignments. From 2016 to Spring 2019, this project was conducted as a field study that required students to search the university's research website to find a lab conducting scientific research, gain access by writing a professional email and scheduling a tour, and write a field observation report. While many students reported this being a profound experience—which even led some to gain jobs as research assistants in labs they studied for the project—inevitably, one or more groups would struggle because of schedule incompatibility or non-response from the labs they contacted. This made the project stressful for these students and the instructor, particularly considering that one of the primary goals for the project was to write about the culture of the specific scientific site which could not be achieved without access to the site first.

One other challenge has been recognizing that students need active support in learning how to collaborate effectively and inclusively with one another, especially when it involves writing. Though most teams were successful and reported an overall sense of satisfaction with their collaborative projects, enough students reported feeling that they simply did not have enough time to meet their teams because of scheduling issues or personal struggles outside of class. In Fall 2022, we carved out the Friday after the start of each new collaborative project as a dedicated team-building time, during which they were expected

to develop teamwork agreements and set their team roles. Additionally, the instructor occasionally had to step in and help students set up expectations for teamwork and collaborative writing.

The student response collected from data suggests that enacting this ambitious syllabus works overall, especially to reach students with diverse interests and motivations in science. We have noticed that no project stands out as the students' favorite, as each student appreciates different critical science literacy and rhetorical skills learned in each. This suggests that the variety of approaches to engaging scientific culture through writing enables STEM students with diverse backgrounds, interests, and goals in science to each find a motivation to write through the course, whether that is through engagement with the written cultures of scientific knowledge production they would like to participate in (Scientific Sites), learning how to fact-check scientific claims that matter to them (Trace that Claim), or understanding competing perspectives on socioscientific issues they care about (Perspectives Project). Centering the tools for inquiry and engagement in scientific culture motivates students to see writing as a worthwhile investment of their time and energy as future science professionals.

Final Reflection

This writing course offers a design that seeks to encourage STEM students to recognize the importance of writing and promote critical literacy required in their respective fields. Our overall success with the course demonstrates that encouraging students to delve into the complex relationship between science and writing not only helps them realize the value of writing for their respective careers, but also encourages them to consider themselves as responsible writers and legitimate members who have the power to change the science culture. We hope this curriculum design will provide fruitful inspiration for writing instructors who find their STEM students resistant to engaging with their courses.

Notes

1. The data mentioned in this study is IRB-approved. IRB number: STUDY00003392.

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