AMERICAN SOCIETY FOR MICROBIOLOGY | JMBE Journal of Microbiology & Biology Education

| Research Article

Student definitions of ownership and perceived ways ownership influences writing in a biology laboratory class

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ABSTRACT Laboratory courses offer a unique opportunity, and sometimes challenge, to engage students in projects where they can experience ownership and authentic science practices. An important science practice is writing, which can lead to increased learning about concepts and science communication. Experiencing a sense of ownership in research can lead to various student outcomes, such as increased motivation, greater interest in research, and higher retention in STEM fields. Although previous work has extracted aspects of ownership from students' descriptions of research experiences, studies have not examined directly how students define and perceive ownership. In addition, we do not have a clear idea of whether a sense of ownership is related to student attitudes toward scientific writing in a lab course setting. To better understand the relationship between ownership and writing directly from students' perspectives, we used analysis of student responses to surveys and interviews in an upper-division laboratory course. Using a grounded theory approach for the analysis of 167 survey responses and 9 interviews, we found that students have varying perceptions of project ownership, with the most frequent being opportunities to contribute ideas and shape the project (autonomy), doing the work, and leadership. Students largely perceived that increased ownership had positive influences on their writing, such as increased understanding and thinking, freedom in writing, and increased motivation. Learning about how students perceive ownership in the context of a lab course is useful for considering how lab course structure may support the development of a sense of ownership and may influence how we can engage students in meaningful writing practices.

KEYWORDS ownership, laboratory class, writing, lab report

Developing skills in scientific practices and reasoning are desired outcomes of lab course experiences, which may be influenced by ownership. Ownership can be fostered during lab course experiences when students can engage in discovery, collaboration, and iteration and make their own independent contributions that affect the direction of the projects (1–3). Previous research has provided definitions of student ownership of learning and research projects. These definitions have been synthesized from education literature (4) and elaborated from linguistic analysis of student summaries of their research experiences (5, 6). From these works, ownership may be thought of as consisting of several aspects (Table 1). These include (i) having a sense of responsibility for the work which may include agency and autonomy (capacity and authority to make decisions); (ii) overcoming challenges faced during the research process; (iii) perceiving that the work is significant or important to the larger scientific community; (iv) a commitment or buy-in to the project, which may include acknowledging the investment of time and effort, and a belief in the value of the work; (v) having a personal connection to the work; and (vi) positive emotions or excitement related to the experience or work. Others have also delineated ownership to be composed of both

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The authors declare no conflict of interest.

Received 20 November 2023
Accepted 30 January 2024
Published 15 March 2024

TABLE 1 Aspects of ownership identified in previous studies

Aspects of ownership previously defined by others	Explanation	References describing this aspect
Responsibility, agency, and autonomy	One has a responsibility for the outcome of the work. Responsibility may include agency (capacity to do the work) and autonomy to set goals and autonomy to make decisions that affect the direction or outcome. Agency, sometimes combined with mentorship, may lead to students seeking help and advice to accomplish their goals.	(2, 4, 5)
Overcoming challenges	One's experience overcoming obstacles and challenges during the research process.	(5, 6)
Significant	One perceives the work as significant to or contributing to the larger scientific community.	(5, 6)
Commitment (buy-in)	Refers to a one's commitment to and involvement in a project; acknowledging the investment one makes in a project, including work, time, money, and a belief in the value of the work (buy-in).	(4)
Personal connection	One has a personal connection to the work or sees the work as an extension of themselves ("identifying with") or relating current work to past experiences.	(4–6)
Excitement or positive emotions	One's positive emotions in response to conducting the work or being involved in science, sometimes referred to as "emotional ownership."	(2, 5, 6)

"cognitive ownership" and "emotional ownership" (2, 6); where cognitive involves the agency within the work and to overcome challenges, and feeling the work is important, and emotional ownership involves positive emotions.

A sense of ownership can be influenced by the educational curriculum. For example, students in a research-based lab compared to a traditional lab more often had aspects of ownership appear in their descriptions of their experience, and greater ownership as measured by the Project Ownership Survey (3, 5, 6). A student's sense of ownership can change over time during a course curriculum, reminding us that ownership is not static (7). Project ownership may also serve as a mediating factor between lab-course experience and student outcomes such as self-efficacy and motivation (7, 8), persistence in science education (5), and intentions to pursue a science career (2). Ownership, thus, is likely an important part of learning in a lab course setting.

Writing is also thought of as an important aspect of lab course experiences. Through writing, students gain benefits such as better comprehension of course content (9–11), greater personal connection to assigned reading (12), increased interest in topics (13), familiarization with the culture of science disciplines (14–16), and connection to the science community (16). The process of building connections among ideas, texts, authors, and across domains and disciplines creates new meanings of previously obtained knowledge and facilitates students' knowledge construction (17).

Our previous research suggested that students had more unique writing (measured by a reduction in common types of plagiarism) when they engaged in lab modules that generate novel findings (discovery) and provide opportunities for responsibility and autonomy to decide on the research question and design compared to when they engaged in modules with less responsibility and discovery (18). Given the relationship between agency and discovery with ownership (2–6), our previous findings led us to question how students in our lab class conceived of ownership and the role of ownership on students' experience engaging in writing in a lab course setting. Previous researchers have synthesized conceptions of ownership derived from student descriptions of experiences (5, 6, 19) and from those descriptions of experience developed the Project Ownership Survey (6). However, to our knowledge, others have not looked at how students conceive of ownership by directly asking them to define ownership. In addition, although prior work has looked at correlations between authorial identity and student's approaches to writing (20), we are not aware of a study investigating how students believe ownership influences their scientific writing in a lab class. As such, we conducted a study to address the following research questions:

1. How do students conceive of ownership over projects in a lab course setting?
2. In what ways do students believe ownership influences their scientific writing in a lab course setting?

We hypothesized that we would identify aspects of ownership that overlap with those previously described (4–6, Table 1) and that we may find aspects that are unique because of asking students directly and asking in the context of an inquiry-style lab course rather than a research experience. In addition, we hypothesized that a sense of ownership would have a positive influence on student perceptions of writing, both in the way they approach and feel about their writing. Findings from this investigation will provide insight on how conceptions of ownership may vary depending on the context (e.g., research experience vs inquiry-based lab course) and how course structure may influence perceived ownership and may provide ideas about how to engage students in more meaningful and productive writing in a lab course setting.

METHODS

Study context

Data were collected from an upper-level biology laboratory course at a large, public R1 university and were approved by our human research protections program (Project number 181885). Only responses from consenting students were included in the analysis. In general, about 30%–50% of students have had some previous lab experience (outside of our class) when they take this course, either in the form of other lab courses and/or working in a research lab. Most students taking the course are third- or fourth-year biology majors. The course focused on theories and practices of recombinant DNA and molecular biology techniques. Students engaged in four projects throughout the course, each with varying levels of complexity and opportunities for students to make choices in the experimental design process. Project #1, called "Agarose Gel Electrophoresis Interpretation," was perceived by the instructional team and viewed by most students (as determined by surveying) to have the least ownership, where students analyzed two DNA samples using Agarose Gel Electrophoresis to determine size and amount of DNA they had in each sample. Students could make a small decision: to choose what volume of DNA to load on the gel and see how that influenced band intensity. Project #2, "PCR Variables," and Project #3, "Ligation Efficiency," allowed students to choose which variables to manipulate and what manipulations (within some constraints) to make. Project #2 allowed students to determine the effect on PCR product yield and quality by manipulating a variable of their choice (e.g., annealing temperature, primer amount, cycle number, magnesium concentration). Project #3 allowed students to manipulate ligation molar ratio and ligation incubation temperature to determine the impact on ligation efficiency. These projects had minimal discovery as the outcomes were already known by the instructors and often by the students. Project #4, called "Site-Directed Mutagenesis," was the project perceived to have the highest level of ownership (66% of students ranked this project as the highest-ownership project). In this project, students used site-directed mutagenesis to design and introduce a mutation of their choice to investigate the effect of promoter sequence on the expression of a reporter gene in *Escherichia coli*. The outcome of the different mutations was unknown to students and instructors, adding a sense of discovery. For all projects, students wrote a short (1–3 pages) scientific report. These reports have the basic components of a scientific paper, including an introduction, a brief overview of the methods, results, and discussion.

Survey and interview data

At the end of the term, an anonymous survey was conducted. The survey was broadly about ownership and writing in the course. Here, we report on the analysis of responses to two free-response questions from the end-of-course survey that were directly related to our research questions. To allow for unexpected ideas about ownership to be

detected, we chose to ask students to define project ownership, as opposed to infer the degree of ownership they felt from responses to forced-choice questions. For this reason, we used our own free-response questions instead of the Project Ownership Survey (6), which provides Likert-Scale questions to assess student perceptions of ownership. The first survey question was to address research question 1: "How would you define ownership over a research project?" The second survey question we analyzed was to address research question 2: "Consider the project you felt you had the most ownership over and compare that to the project you felt you had the least ownership over. Do you think your sense of project ownership influences how you write your report? Please explain how and why or why not."

We chose to not collect demographic data on surveyed students because it was not our goal to correlate perceptions of ownership to demographics, rather we wanted to characterize student perceptions across our course population in general. The vast majority of students in the course are seniors and biology majors. Most have taken at least one undergraduate or college-level lab course prior to this course. A total of 167 survey responses were collected from 5 course sections taught by 4 different instructors (37, 31, 62, 37 respondents from each section). All course instructors followed the same lab curriculum, and all had their students writing the same style of scientific reports for all four projects.

Interviews were also conducted at the end of the course to obtain additional insight into the students' survey responses and ensure students were interpreting the questions the way we intended. All students enrolled in the course were invited to the interview via an email link sent through the course management system. All interviews were confidential (no student identifiers recorded) and voluntary. Those who participated were given $15 cash. A total of 18 students volunteered and 9 were randomly selected to be interviewed. The interview questions were the same as those on the survey, but after each response, the interviewer (author AY, who was not a course instructor) also asked follow-up questions to elicit further elaboration from the students, such as "what is your reasoning for your response" or "could you explain this in more detail" or "what did you mean by [student wording]?"

Survey and interview data analysis

After removing responses that were incomplete, we analyzed 158 responses for question 1 (define ownership) and 159 responses to question 2 (does ownership influence approach to writing). An iterative and grounded theory approach (21) was used to developing coding rubrics and code responses to the questions asking students to define ownership and to explain how ownership influenced their writing. The two rubrics illustrate the results of our analysis: the themes we saw in student responses about ownership, and how ownership influences their writing. As the coding rubrics represent our results, they are presented in the Results section (Table 2, rubric for student definitions of ownership and Table 3, rubric for student responses about how ownership influences their writing). What follows is a description of how we generated these rubrics.

First, a random set of 20 survey responses were analyzed by each author independently to come up with themes they saw emerging from the responses, including frequently identified words and descriptions for the emerging themes. Upon meeting and comparing themes, we developed a set of themes (codes), and typical key words or phrases that exemplified a theme, as a coding rubric. Then, a second set of 20 responses were randomly chosen and examined independently using the agreed upon coding rubric. The coders then met and added clarifying definitions to the rubric. Prior to discussion, the two coders achieved 92%–97% similarity in coding student responses using the rubrics. With discussion, a 100% consensus was reached, and AY coded the remaining responses.

After the interviews, and prior to coding the survey response, the researchers met to discuss the interview responses in a broad, qualitative sense, identifying some emergent themes, and discussing if we felt the students interpreted and responded to the

TABLE 2 Analysis of student definitions of ownership in response to the question "How would you define ownership over a research project?"[a]

Theme	Description of theme	Frequently identified words and phrases, and example student responses	Relation to previously defined aspects of ownership (Table 1)	Percentage of student definitions containing theme
Work	The work time and effort that is put into the project, including completion of laboratory tasks, analysis, and/or writing.	Conducting experiment; analyzing data; writing reports, author of papers "I believe that ownership is defined by the continuous execution of a research project. The individual(s) that puts in the work to see the project idea become a reality should be awarded with the ownership." "The person who did the most work on the project."	Related to Commitment (Buy-in) (4); however, our theme differs in that it is solely based on work-related effort and work-related tasks and does not necessarily articulate a commitment to the project goals or beliefs about the value of the project.	56%
Autonomy	Opportunities for or experiences of contributing one's own ideas to the project and making decisions, such as choosing procedures, designing research questions, choosing methods of analysis.	Coming up with hypothesis or experimental design; procedure planning; make decisions; control direction of the project "Being part of the conceptual creation and overall procedural planning of a research project" "Ownership over a research project means coming up with the purpose, methods, experiments and analysis yourself, and not copying other people's works." (Also coded in the theme "Ethics")	Related to Responsibility and Agency (4–6), however our theme solely focuses on the aspect of decision making (autonomy) and contributing ideas, but not necessarily an articulation of the responsibility one feels over the project or the outcomes.	51%
Leadership	A role in supervising, guiding, or monitoring people working on a project, or the project itself	"I would define ownership over a research project as some leader who is in charge of the whole project and has responsibility over everyone who works for him or her as well as someone who designates jobs and oversees the flow of the project"	Related to Responsibility (4), however, our theme more specifically captures a responsibility over others or the work of others	18%
Responsibility	One's personal responsibility for project outcomes; an investment beyond work time; not just the act of making a decision, but the responsibility that comes with those decisions	"Responsible for outcomes of the project" "If I have ownership over a research project, I conduct the experiment and am responsible for the results of the experiment." (also coded in theme "Work" because of indicating they conduct the experiment) "Possession and responsibility of the data received from experiments conducted in your research project."	Responsibility and Agency (4–6), focusing specifically on the responsibility for the products or outcomes	5%

(*Continued on next page*)

TABLE 2 Analysis of student definitions of ownership in response to the question "How would you define ownership over a research project?"[a] (*Continued*)

Theme	Description of theme	Frequently identified words and phrases, and example student responses	Relation to previously defined aspects of ownership (Table 1)	Percentage of student definitions containing theme
Funding & Institution	Acknowledgement of the funding investments, or the institutional investment and stakes in research	Provide funds; research institution is usually mentioned "To me, ownership over a research project is whoever is funding the project." "A research project belongs to university"	None	5%
Understanding & Knowledge	Describing the knowledge or understanding required or developed while working on a project	Understanding the topics, process, underlying mechanisms; being confident about the content "I would define it as the ability of someone to know what is going on in their investigation in addition to be being confident in the content of the research project"	May be related to Agency (4, 5); knowledge or confidence about knowledge/understanding could relate to the ability to do a task	4%
Ethics	Describing a responsibility to the ethical standards of conducting research, often centered around the ethics of writing about their work	Using one's own data; no plagiarism; giving credit to outside sources "I would also define ownership as using one's own knowledge and language in writing a report and giving credit to outside sources used."	An extension of Responsibility (4–6), but more specifically a responsibility related to the ethical standards of the course or discipline	2.50%

[a]Key words in sample student responses are bolded for emphasis. A total of 158 student responses were coded. A single response from an individual student can contain multiple themes, therefore the total percentage of student responses is above 100.

questions the way we intended. The interview responses were not included in the quantitative coding; however, we examined interviews for examples of the themes that emerged from coding and included some example responses in the results section.

RESULTS

How do students define ownership?

To learn about the definition of project ownership directly from students' perspectives, the first question on the survey was an open-ended question that asked, "How would you define ownership over a research project?" Seven themes emerged from student responses (Table 2). The two most frequently mentioned themes were *Work* (doing work) and *Autonomy* (opportunities to make decisions and contribute ideas).

About 55% of the students considered the work involved in the execution of the project as a defining factor of ownership (theme: *Work*). However, the amount of work necessary to claim ownership varied, from extensive to just some work involved, as illustrated by comparing these two student statements:

> "Ownership indicates that a certain individual has performed a majority of the background research, all the protocol/analyses and data retrieval of the project".

> "Even if you didn't like write anything, you just made like a figure, [you have ownership over a research project]."

About 51% of the students described aspects of *Autonomy* as part of ownership. This ranged from creatively contributing the idea to initiate a project, freedom to develop their own hypotheses and research questions, to making decisions about experimental procedures and analysis. This was echoed by one student's interview response,

> "Ownership is like, if you have an experiment, how much of that experiment you are able to come up on your own or like have control over the design of the experiment."

Moreover, 20% of students mentioned both the theme of *Autonomy* and *Work* in their definitions of ownership, but some students did not feel that both were necessary to claim ownership, as one student in our interview pointed out,

> "I do think that the person that really designed the research is the real owner, but I do feel like I have some ownership if I at least like participated and helped in the work of it."

Despite many students indicating *Autonomy* and *Work* as an aspect of ownership, very few (5%) included a *Responsibility* for the outcomes of their project in their definitions of ownership. *Responsibility* differed from *Work* and *Autonomy* because it was acknowledging not just the effort to make decisions or the work to conduct the experiments, but that one was responsible for the outcomes and products of that work.

The theme of *Leadership* emerged in nearly 20% of student definitions of ownership and indicated an overarching role in supervising, guiding, and monitoring the project

TABLE 3 Qualitative analysis of student responses to the question "Do you think your sense of project ownership influences how you write your report? Please explain how and why or why not"[a]

Theme	Frequently identified words and descriptions	Sample student responses	Percentage of student responses containing theme
Understanding and Thinking	Know more about the topic; comfortable with the material; easier to recall the process	"yes because for the higher ownership project, I had more variables under my control so i had to think about the causes of each of the variables i changed" "Yes, when I had a sense of ownership over the project, the lab report was easier to write because having ownership helps ones understanding of the project."	50%
Freedom & Ease in Writing	Having more to say; better at or easier writing of discussions and explanations of results; unique writing; less reliance on rubric/lab manual	"Yes, having more ownership allowed me to make my own conclusions based on what I thought the outcomes would be." "Yes, the more ownership I had, the easier time I had writing the Discussion, because I had to make it clear why I made certain decisions and what I hoped I would see from my decisions"	34%
Motivation	Working harder; willing to put effort	"Yes. Being able to control many variables of the experiment made me feel like I was more responsible for how I analyzed the data. It made me put more effort in understanding the experiment in a form of a story, which made me feel like I had more ownership." "Yes, because having ownership gives me more of a reason to work harder on the report."	12%
Personal Connection	The material being more personal; feeling more responsible; caring more; more attached; representing oneself	"Yes something that you have more ownership of makes it more personal when writing a lab report" "I cared far more about the lab report where I had control. It was exciting to describe how something I decided affected the results." (also coded as "positive feelings")	10%
Positive Feelings (toward the project and oneself)	Passionate; interested; confident; exciting; fun	"Yes. It was easier to write a report about something I was passionate about" "Of course, because it gives a sense of confidence that I have a grasp over the material to write a better discussion."	10%

[a]A total of 101 students (out of 159) reported that ownership *did* influence their writing; analysis of their explanations of how ownership influenced their writing is reported here. Multiple themes can be found in a single student's responses, so the total percentage is higher than 100.

or people. Ownership definitions with aspects of *Leadership* were focused on the role of supervising or guiding others working on a project. For example,

> "Ownership over a research project means that you came up with the original ideas and guided (if applicable) other researchers" (this statement was also coded as Autonomy)

A small fraction (5%) of student's ownership definitions included the theme of *Funding & Institution*, indicating that an investment of funding by someone or an institution, or that the place of research itself was a factor in how ownership was determined. Another theme that was found in only four responses, but we feel is worth noting, was that of *Ethics,* in which students specifically articulated a responsibility to produce work on their own and follow the ethical standards around writing (avoiding plagiarism) (Table 2). Another infrequent but notable theme was that of *Understanding & Knowledge* (4% of the 158 responses)*,* where some students indicated that being able to understand the research or that one possessed knowledge about the project was a defining aspect of ownership. For example,

> "I would define it as the ability of someone to know what is going on in their investigation in addition to be being confident in the content of the research project"

and,

> "Understanding the research project to its entirety, in terms of the process, why, and people running each part."

Do students feel that ownership influences their writing?

Students were asked to consider the project they felt they had the most ownership over and then asked if they felt that a sense of ownership influenced their writing. Most students (64%) answered "yes" that they thought a sense of ownership influenced their writing; 24% said a sense of ownership had no effect, and 12% did not clearly indicate if there was or was not an influence. Students were asked to explain how ownership influenced their approach to writing, and five themes emerged when looking at responses from students who indicated an influence of ownership on their writing (Table 3). About 50% of the students reported a relationship between ownership and the theme of *Understanding and Thinking*, and impacts on writing as a result. For example:

> "In terms of discussion, I think I was able to write more thoroughly for the project I felt I had more ownership in because since we controlled more of it, I understood more of it."

and

> "….since ownership probably would help you understand things better, it could be like ok if I understand, like to be able to have that sense of ownership and be able to change things, like I have to understand how they're changing and like why they're changing so I guess that helped. I would say it definitely helped writing our report because you'd have a, just in terms of like better understanding of what you are doing and how to explain things better."

A small fraction of students (10%) reported that ownership influenced *Positive Feelings* toward their projects, writing, or themselves:

> "I felt much more confident in my abilities to put together a successful lab report when I felt I had the most ownership over that project."

For some students, *Understanding and Thinking,* and *Positive Feelings* were related, as expressed during an interview,

> "Instead of just going into the motions, like you're really like a robot … and I don't know
>
> what I did, so how am I supposed to explain this … it feels good to understand why things are happening."

About 34% of the students expressed a *Freedom and Ease* in writing as an effect of project ownership. According to these students, with this sense of freedom, they were able to discuss and explain their ideas,

> "Yes, having more ownership allowed me to make my own conclusions based on what I thought the outcomes would be. Having little ownership felt like writing a worksheet, as everything was already laid out."

Some students (about 10%) reported that ownership influenced the *Personal Connection* they had with the project and, in some cases, a heightened sense of excitement (also coded with the theme *Positive Feelings*):

> "I cared far more about the lab report where I had control. It was exciting to describe how something I decided affected the results. For the other report, I had very little investment because it was not my decisions""

Finally, about 12% of students expressed that ownership affected their *Motivation* toward the writing, indicating that they were willing to put in the necessary work. For some, a *Personal Connection* was the *Motivation:*

> "Yes. If i have more project ownership, the material is more personal to me, therefore i want to put in more work"

About 24% of students (39/159) did not think the level of ownership affected their writing approach (they answered "no" when asked if ownership influenced their writing). However, a small number of students from this group (4/39) did describe that personal connection or positive feelings and motivation were present in their increased ownership writing experiences. Just over 40% of the "no" group (about 9% of the total surveyed population) indicated that the lab report guidelines or their previously established writing style dictated how they approached writing.

There did not appear to be a meaningful relationship between how students defined ownership and if they felt ownership influenced their writing, as there was an even distribution of the ownership definition themes among the students who said "yes" and "no" to whether or not ownership influenced writing. The only exception to this was for the ownership theme of *Funding & Institution*: of the eight students who include this theme in their ownership definition, six said ownership did not influence writing and one said it did (the eighth did not have a conclusive answer to the second survey question). However, with such a small number of students mentioning this theme, we are not confident making a claim that there is a meaningful relationship without further investigation.

DISCUSSION

Students in our lab course primarily define ownership as autonomy to contribute ideas and putting in the work

To learn about how students in an upper-level biology lab class conceive of project ownership, we directly asked students to define project ownership. One of the most common themes that arose from student responses was *Autonomy,* including having one's own idea influences a project, designing experimental conditions and manipulating experiment methodology, and coming up with hypotheses. *Autonomy* was noted as an important factor in developing research self-efficacy in a study by Gin et al. (22), and given the value our students placed on decision-making opportunities, we see *Autonomy* as an important element of lab course design. The right to make choices that control the overall direction of a task is encompassed by the *Right and Responsibility* category in

Wiley's definition of ownership (4, Table 1). It is this right to control and influence that may promote ownership over the task (4). Wiley described how *Right and Responsibility* can encompass not only autonomy and agency but also a sense of responsibility which arises together with students' freedom of control because students are now partly in charge of the research process and, thus, responsible for the results obtained from that process (4). Very few students in our group (5%) stated aspects of responsibility over outcomes of their work when defining ownership; however, some (18%) did include an element of responsibility in the form of *Leadership* (e.g., guiding and/or being responsible for others or the work of others). A lack of articulating a responsibility for their outcomes could be related to the low-stakes nature of the work in the class; although students had some decision-making authority, their research outcomes are not needed beyond the scope of a course (e.g., for a publication), nor were they penalized if the experiments did not generate robust results. Furthermore, without a longer-term commitment to a project, there may be less a need or opportunity to feel a sense of responsibility for the outcomes. Broad or novel relevance of the results generated in a lab class, beyond the context of the course, has been shown to positively impact cognitive ownership (2, 3) and emotional ownership (3). We postulate that if the results of our lab class were broadly relevant, and the importance of this was communicated to students, more of the student population may have identified a responsibility for the outcomes as part of their definitions of ownership. It would also be enlightening to survey and interview biology researchers to determine how frequently they include ideas about responsibility in their conceptions of ownership.

A small number of students had a specific type of responsibly in their definitions of ownership and that was *Ethics* (particularly over conduct and writing). We see this as related to the context; a lab course had multiple writing opportunities and did include lessons on ethics and integrity related to writing.

Another common theme in our students' definitions of ownership was *Work*. Over half of the surveyed students included descriptions of time or effort invested in a project when defining ownership. Some of our students thought that only those who were highly devoted to their projects and did continuous work should claim ownership. In contrast, others claimed that any amount of work or contribution allowed one to claim ownership. *Work* is a variation of the *Commitment* and *Buy-in* aspect of ownership defined by Wiley (4, Table 1). Part of *Buy-in* includes how an individual spends time and effort on a task and that the degree of investment varies among individuals (4). However, Wiley also describes how *Buy-in* can encompass a belief in the value of the work. It was not clear from our student definitions that work effort was tied to valuing the work; in fact, no students in our study clearly articulated a value belief as part of their ownership definitions. Hanauer et al. (5) did not identify an aspect of ownership that encompassed students describing their work effort specifically although they did identify a theme of personal achievements (in discovery, for example), which may be connected as an outcome of effort and work. We postulate that *Work* was a common theme that emerged in our study because we asked students directly for their definitions specifically in the context of an inquiry-based lab class. The fact that it is a class, and not a true research experience, nor generating broadly novel results, may influence how students frame the experience; they may see it as work that needs to be done, and there may not be the same opportunity to develop a non-work commitment to a project, as one may do in a real research setting. To understand the true impact of this framing, it would be interesting to compare student definitions of ownership when asked directly in the context of a research-based lab class (course-based undergraduate research experience) or when they are engaging in research in a non-class setting, and specifically probing students about the value they place on work and outcomes during interviews.

One aspect of ownership that was identified by others, but not in our study, was *Personal Connections* (4–6, Table 1). *Personal Connection* is defined as the personal identification a student has with a task, or seeing that the project extends from their previous experiences, or is relevant to personal interests. None of the students

in our study mentioned personal connections with a project in their definitions of ownership. This is within our expectations. Since the project topics in our lab course were all pre-determined, it was less likely that the projects would extend from our students' previous experiences. Hanauer and Dolan (6) reported that students engaging in more authentic research, compared to those in a traditional lab setting, had increased cognitive and emotional ownership but did not show gains in having "a personal reason for choosing the research project they worked on," suggesting that despite engaging in many authentic research practices, personal connections can be challenging to form. Students in our group did, however, mention increased personal connections and positive feelings when asked how ownership influenced their writing, so there may be opportunities for both cognitive ownership (responsibility, agency, autonomy) and emotional ownership (personal connections, positive feelings) within the constraints of a course, for example, by engaging in writing (discussed more below).

Agency was another aspect of ownership that has been identified by others (5, 6, Table 1) but was not specifically identified in our student definitions. Agency is different from autonomy, in that autonomy is related to the authority to make decisions, but agency refers to the ability, capacity, and actions to accomplish goals. Hanauer and Dolan (5) often saw agency come up when students described what they did to overcome challenges; that they sought help and figured out ways to keep the project going despite challenges. *Agency* may have come up more in Hanauer and Dolan's study because they were asking students to describe their research experiences but not how they defined ownership. It may be that students did feel or experience agency in our class, especially in combination with *Autonomy* to make decisions about the project, and that they had to take actions to overcome challenges and complete the project and troubleshoot unexpected results; but that those agency experiences were not salient aspects of a definition of ownership. A few students in our study indicated that having knowledge and being confident in their understanding of the project was part of ownership (*Knowledge & Understanding,* Table 2, 4% of student responses). Confidence in one's knowledge could relate to one's ability to do the tasks necessary for a project and thus contribute to agency. Further investigation about how students experience *Agency* in the lab class would be worthwhile to understand how this potentially important aspect of a research experience can be incorporated within the constraints of a class.

An infrequent aspect of ownership that was unique to our study was that of *Funding and the Institution* (5% of responses, Table 2). This theme may indicate that notions of authority overlap with those of ownership for some students. It could also be related to an awareness of the significant financial commitment involved in research, or related to the way ownership has been framed in outside of class research experiences. This theme did not emerge during interviews, so we lack additional insight as to why or how these aspects became part of some student definitions of ownership. Additional discussions with students to understand the role authority plays in ownership would be interesting.

Students report a positive effect of ownership on their scientific writing

We wanted to investigate if students perceived that a sense of ownership influenced their writing. Autonomy in a lab course setting may increase self-efficacy and investment in work (22). If autonomy is a core aspect of ownership, from the student's perspective, we hypothesized that a sense of ownership may influence the way students approach or perceive an associated writing task, such as being more invested and feeling like they have more unique ideas and thoughts to contribute to the writing. Indeed, nearly two-thirds of the surveyed students reported positive effects of project ownership on their writing experience. Among students who reported positive effects, 50% thought their understanding of course concepts or the project was influenced or that there was more thinking involved in the writing of projects for which they had higher ownership (theme of *Understanding and Thinking*, Table 3). This may be because the higher-ownership project involved more complex molecular biology topics, and the results were not always as expected, so increased critical thinking and understanding

was required to make sense of and write about the results. Previous studies have indicated how the incorporation of writing exercises in science instruction assists critical thinking, better comprehension, and deeper learning (9–11, 20). Our results suggest that increased ownership could encourage increased critical thinking. As explained by some interviewees, with ownership, students feel obligations to or are more eager to understand the project content to engage in the writing. Interestingly, despite a strong connection between ownership and *Understanding & Thinking* in writing, only 4% of students included aspects of *Understanding & Knowledge* in their definitions of ownership (Table 2). We postulate that ownership may influence the understanding and thinking outcomes (or perceived outcomes) of engaging in lab work but may not be fully realized without opportunities to articulate their thinking about the work.

In addition to a feeling of understanding the work, many students reported an increased sense of *Freedom and Ease* in their writing when they perceived greater ownership over the project. Multiple student statements indicated this freedom and/or ease influenced their writing of the Discussion section of the report, where they are writing arguments and explanations for their results. As some of our interviewees indicated, students with feelings of ownership tended to view their writing as something unique, so they were free to express original thoughts. According to one of our interviewees, it was easier than expected to describe and explain unexpected data simply because they knew every group was going to obtain different results and they enjoyed sharing unique findings. This is encouraging, because although the overall project idea did not represent or extend from students' prior experience, the autonomy to manipulate a crucial experimental condition which leads to discovery could greatly impact students' personal connection to the uniqueness of the results, and perhaps their authorial identity.

Ownership appears to have an impact on affective domains in the context of writing, where a little over 30% of responses indicated that ownership influenced *Motivation (12%)*, or *Personal Connections (10%)*, or *Positive Feelings (10%)* toward the project, the writing, or their abilities (e.g., "interesting," "meaningful," "enjoyable," "confident," and "well-prepared"). Sometimes, there were connections between affective domains, where positive feelings were described by some as a reason for increased motivation to put time and effort into writing. These may be indicative of changes in emotional ownership. Cooper et al. (3) and Corwin et al. (2) found that broadly relevant/novel results and discovery, iteration, and collaboration positively influenced emotional ownership, respectively. Based on our results, we suggest that increased autonomy, possibly combined with discovery in the form of unknown or unexpected results (in our class), may increase emotional ownership when there are opportunities to write about the work.

The way students defined ownership did not correlate to their reported belief that ownership did, or did not, influence their writing. This suggests that, although a combination of ownership and writing may influence the way students experience projects and outcomes in a lab class, the way students conceive of ownership may not dictate whether they perceive benefits of ownership with their writing.

Limitations

Adding upon expert definitions of ownership and those deduced from student's descriptions of research experiences (4, 5), our study further provides insights about how students perceive, and perhaps experience, ownership in a lab course setting. However, students who participated in our research were all from the same upper division biology lab course, and thus their responses are likely limited by the course setting. In addition, we only focused on students' perceptions of how ownership influenced their writing, but we did not assess the quality of their writing in high- versus low-ownership scenarios. Further studies may investigate if changes in ownership impact writing outcomes.

Conclusions and implications for teaching lab classes

Previous work has established that ownership is dynamic and multi-faceted and one that can be influenced by engaging in research experiences (2, 3, 7, 19) and curriculum design factors (6, 19, 22). Here, we have found some diversity in conceptions of ownership, but they commonly include being able to have authority to make decisions or have their ideas influence a project and putting in the work necessary to complete a project. When designing lab courses, it may be important to ensure students have sufficient opportunity to recognize the value of their work in the project and have authority to shape the project. Despite significant constraints in a large-enrollment lab class, we have found ways to provide students with opportunities for autonomy. For example, although the broad research goals are provided (for example, we want to understand how homology repair template design affects the frequency of mutation incorporation after Cas9 cutting), we give students the choice of which questions to investigate (what aspect of template design to study), and more recently *how* they want to investigate them (autonomy to design the specific repair template sequences, and what experimental samples they set up). To add discovery, we encourage students to pursue questions that do not have an obvious or previously reported answer. More recently, in this lab class, we have students across multiple sections pool their results into a shared data set. With this larger data set, students are tasked with determining how to analyze the data to not only best address their question but also choose an additional question to answer (using data generated by other groups, like mining a public data set). We believe that autonomy at multiple levels (what to investigate, how to investigate, and what final analysis to do and present) may lead to a greater sense of ownership over the project and their final writing product.

We found that most students in our studied population report a positive relationship between a sense of ownership and the writing process. Writing may be one way for students to deepen their understanding of the material and research (9–11), and we believe a combination of ownership and writing opportunities may be valuable components of a lab course to engage in more critical thinking and generate positive feelings about the work. Given that broadly relevant results may positively impact ownership (3), we recommend finding ways to increase the broad relevance of student writing, for example, by producing a public-facing blog, a paper reviewed by someone outside of the class, presenting work to others in the department in the form of a research colloquium. Student's autonomy in a project that influences the data generated and, thus, influences what is written about may be one way to create opportunities for ownership and a positive writing experience.

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