Exploratory Study on the Use of Primary Scientific Literature

in Undergraduate Education:

Faculty Practices and Perceptions

by

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Master of Science

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ABSTRACT

Calls for changes in science education over the last several decades have contributed to a changing landscape of undergraduate life science education. As opposed to simply lecturing at students and expecting them to recite science facts, there has been a strong push to make systemic changes so that students not only know pertinent science content, but also walk away with critical science process skills. There have been suggestions to create environments that focus on goals such as evaluating scientific evidence and explanations, understanding the development of scientific knowledge, and participating in scientific practice and discourse. As a part of the call for increases in student participation in science practice, we've seen suggestions to increase student exposure to the tools, techniques, and published research within various science fields. The use of primary scientific literature in the classroom is documented as being a tool to introduce students to the nature of scientific reasoning, experimental design, and knowledge creation and transformation. Many of the current studies on primary scientific literature in undergraduate courses report on intensive course designs in which students interact with the material with very specific goals, as outlined by the authors and researchers. We know less about the practices that take place in typical undergraduate settings. This exploratory study looks at information provided by a national sample of faculty that alludes to what sort of practices are taking place and the reasoning for doing so. Through analysis of both closed-ended and open-ended survey questions we have found that faculty are engaging students with primary scientific literature for many reasons and in a variety of ways. We have also attempted to characterize the way in which faculty view the body of scientific literature, as members of the research community. We discuss the implications of faculty views on the utility and value of the body of scientific literature. We also argue that those perceptions inform how the material is used in the undergraduate classroom.

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CHAPTER 1

INTRODUCTION

In regards to formal education, the National Society for the Study of Education (1960) stated the following:

> "Science is more than a collection of isolated and assorted facts…A student should learn something about the character of scientific knowledge, how it has been developed, and how it is used."

This argument for going beyond teaching only science facts can be found in education reports and reforms spanning decades. In its 1989 report *Science for All Americans,* the American Association for the Advancement of Science details the importance of understanding how scientists are completing their work and how they go about reaching conclusions. The report also emphasizes understanding the limitations of scientific endeavors, and the importance of analyzing conclusions reached from that work. In the 1996 *Taking Science to School* report, the National Academies of Science argues that life science education, reaching from kindergarten to introductory college courses, has done a disservice to students by focusing too heavily on simply teaching scientific explanations of the world. The report claims that critical skills needed for 1) evaluating scientific evidence and explanations, 2) understanding the development of scientific knowledge, and 3) participating in scientific practice and discourse are historically not taught to or gained by students and that, in fact, they should be. This problem is echoed in the literature in descriptions of students being asked to only remember facts, rather than learn the ways of thinking and analysis that characterize science (Lord 1998; Alberts 2009).

Science education literature specifically cites the significance of *undergraduate populations* needing to be taught in environments that reflect science process (National Research Council 2003, AAAS Vision and Change 2009, White et al. 2013,). Duncan et al. (2011) suggest implementing curriculum design that emphasizes the open-ended nature of biological investigation as a way to model the process of science. The American Association for the Advancement of Science (2009) report *Vision and Change: A Call to Action* argues that life science education should relate to the real world, be inquiry-driven, and also mirror the scientific process. In these contexts, the "process of science" or "science process" is largely described as that endeavor by which we attempt to design and carry out research based on existing structures, knowledge, and observations of the world-from which we then report results and observations with considerations for repetition, limitations, and potential implications. We follow up by considering how to utilize this new information or alter our existing knowledge base to reflect different findings (DeBoer 1991; Handelsman et al. 2004). Proponents of changes in the landscape surrounding science education associate understanding of the process of science as being a component of overall scientific literacy. Scientific literacy has been defined as simply knowing about the content of science, however, there are arguments for a more substantial definition for scientific literacy. In the context of science education, the definition of scientific literacy has evolved to encompass understanding and application of the process of science, as well as understanding of science content (DeBoer 2000).

Those faculty members who work directly with undergraduates have also reported on the types of skills students within undergraduate life science programs should be obtaining. In a 2010 study on faculty perceptions of students' science skills, 154 faculty reported on the types of skills they thought students should acquire as a component of their science education. Faculty rated interpreting data, communicating results, designing an experiment, reading and evaluating primary literature, and conducting an effective literature search among some of the most important skills, with those skills receiving a 4.5 or higher (on a Likert scale 1-5) in average level of importance. Faculty also self-reported on the significance of other skills not included in the list provided by researchers. Faculty suggested that students should also be able do the following: apply science to life and know what science is and what science is not. Though faculty in the study provided valuable information about the skills they perceive students as needing, 67% of respondents reported that they felt they did not spend adequate time teaching those skills (Coil et al. 2010).

Much of the same science education literature that details the need to improve students' exposure to the process of science also provides recommendations for doing so. Namely, implementing course designs that teach students more about scientific thinking and the "process of science" than traditional, content-only courses. A common strategy for increasing students' exposure to the process of science is by creating environments in which students actively learn science process skills and are given examples of science in action (Herrington 2005; Alberts 2009). Recommendations have included creating "inquiry-based" learning environments, such as laboratory courses or programs in which students take part in research, creating “active learning” environments for students to better engage with material outside of a traditional lecture course, designing coursework in which students can connect content to the “real-world,” and incorporating interdisciplinary courses within life science programs (AAAS Vision and Change 2009; Carnegie Institute for Advance Study Commission on Mathematics and Science Education 2009 Report; Robertson 2012; Freeman et al. 2014).

The use of primary scientific articles in the classroom is documented as being another pathway to teach students more about the “process of science.” Peer-reviewed scientific literature has been called “central” and “essential” (Pall 2000) for understanding how science works and how it differs from other human endeavors. This argument for the use of primary research articles in undergraduate education is often framed as a response to the limits of other course materials; traditional materials such as textbooks present science as a concrete set of natural laws and facts and fail to show students how the scientific endeavor takes place (Duncan et al. 2011), or materials similar to textbooks do not adequately or fully cover certain course content.. The primary scientific literature is argued as having “unique potential” (Muench 2000) to introduce students to the nature of scientific reasoning and to promote more authentic scientific thinking within students and within science education environments (Gillen 2006; Yarden 2009; Hoskins et al. 2007; Wenk and Tronsky 2011). It is also argued to be indicative of how “knowledge” or what we understand about the living world, is created and has transformed over time (Houde 2000).

The use of primary research articles as supplemental material in undergraduate science contexts has been reviewed in various studies. Kozeracki et al. (2006) describe a structured, research-intensive program that includes reading and presenting new material in the field as giving students an advantage when applying to graduate school. Wenk and Tronsky (2011) show gains in *student understanding* of primary scientific literature after nine weeks of "intensive focus on critical reading". In their 2007 study, Hoskins et al. apply the CREATE (consider, read, elucidate hypotheses, analyze and interpret the data, and think of the next experiment) method using primary scientific literature and measure improvements in students' ability to critically read and interpret data and understand complex content. Not only do these studies seem to be an effort to share effective practices, but they also offer concrete recommendations for doing so. For example, Smith (2001) provides a guide for implementing departmental change towards improving biology literacy with the specific goal of increasing student comfort with reading primary scientific literature. Schinske et al. (2008) propose a process by which instructors can by having students analyze a figure, analyze an abstract, and "engage students in the process of science" by composing their own journal article.

As a whole, we see good reasons for using primary research articles in the undergraduate science classroom. However, these studies overwhelmingly show the effectiveness of their particular course designs, in terms of very specific and tangible outcomes. Measured outcomes include students successfully identifying statistical tests (Rabin & Nutter-Upham 2010), feeling "more comfortable" with scientific literature (Smith 2001), understanding the research questions and explaining concepts (Wenk &

Tronsky 2011), preparing a presentation based on an article (Glzer 2000), gaining confidence in analyzing primary literature (Janick-Buckner 1997), reporting having a "positive view" towards scientific writing (Schinske et al. 2008). They do not explicitly measure student understanding or knowledge, in terms of *understanding more about the process of science or the formation of scientific knowledge*. Yet, authors often make inferences about this type of additional or supplemental knowledge as being gained by students. This reflects what may be invalid assumptions of what types of skills and knowledge students are gaining from these experiences. If the researchers in these studies argue for the use of primary scientific literature as having such high potential, in terms of teaching students more about *the nature and process of science*, then undergraduate faculty members could also hold this same view. This may be reflective of differences in how faculty or researchers utilize and perceive this material versus how students utilize and perceive this material. Regardless, there is a gap in the literature regarding the use of primary scientific literature in more typical undergraduate education environments. More specifically, we lack information from instructors themselves on *how* primary scientific literature is actually being used in the undergraduate classroom and *why*.

CHAPTER 2

METHODS

I. Research Questions

1) How do instructors describe their current teaching practices surrounding the use of primary scientific literature in undergraduate courses?

2) What factors could be contributing to those teaching practices, specifically when using primary scientific literature with undergraduate students?

To address the research questions, I developed an anonymous survey (See Appendix A). The survey was designed as an exploratory measure and contains multi-item inventories, as well as open-ended questions, intended to help describe the use of primary scientific literature in undergraduate courses. To answer the first research question, I developed items on the survey that addressed the following: number of students in classes, whether classes are upper or lower level, the amount of article material used over the quarter or semester, time spent on material both in and out of class over a quarter or semester, activities students completed with material, and whether or not anyone evaluated students gains or outcomes from experiences with primary scientific literature.

To address the second question, I developed items on the survey to collect data on instructor demographics, reported reasons for using primary scientific literature, reported reasons for not using primary scientific literature, whether or not instructors had a role in deciding to use primary scientific literature, and instructor perceptions of what the body of scientific literature represents. I hypothesized that faculty would be utilizing primary scientific literature in a wide variety of activities, with both tangible, as well as inflated or abstract reasons for doing so. I also hypothesized that faculty would report using primary scientific literature with undergraduates for reasons that reflect those faculty's own association with the primary scientific literature.

The target population were faculty at research institutions. This population was selected for various reasons: their role as both educator and researcher, their affiliation with a scientific community of practice, and their role as an author on published primary scientific research articles. I randomly selected universities from the list of "very high research activity" institutions from 2008-09 data sets, as provided by the Carnegie Foundation for the Advancement of Teaching. I then solicited prospective participants from programs and departments identified as "life sciences" via the university website. Departments included molecular, cellular, organismal, and developmental biology, as well as ecology, evolution, and genetics. I sent a recruitment email to all faculty members listed within a given department and containing email contact information. The group I emailed included, but was not limited, to emeritus professor, full professor, associate professor, adjunct professor, post-doctoral, instructor, and lecturer. Seventy two participants agreed to take part in the survey. I included sixty-eight participants in the analysis after several surveys were removed for incompleteness.

II. Survey Question Development

A. Representation

As someone who has published article(s), what does the body of primary scientific literature represent?

This question was developed in an attempt to describe what the body of scientific literature represents. This was directed to all participants who said that they were an author on at least one primary scientific article. All participants who completed this question had also previously reported that they have taught undergraduates at some point in the last two years. Responses for this category were coded using elements of both grounded theory and content analysis. Grounded theory is a qualitative analysis technique that can be used to essentially let the data speak for itself; a researcher should attempt to objectively identify emergent themes or concepts from the data, without imposing pre-ordained or constructed categories (Glaser 1978, 1992). I also chose to use elements of content analysis using a directed approach (Hsieh 2005). This method was used to situate the data within a context, based on existing literature or an existing theory. Responses were reviewed multiple times before assigning any form of coding. One should note that due to the impossibility of being truly objective in quantitative analysis, the categories that resulted from these responses are not necessarily indicative of inherent properties of the responses, nor are the emergent categories necessarily accurate reflections of what participants may have intended to convey. Coded responses for this question reflected four emergent categories: foundation for (34%), embodiment of (27%), product of (24%), and a historical account (15%). These categories were coded in consideration for the notion of what the body of primary scientific literature may represent, as well as the notion of its perceived or actual utility.

B. *Practices using primary scientific literature*

The following questions were developed to gauge current practices surrounding the use of primary scientific literature in undergraduate science education:

1. In the time that you have taught undergraduate courses, have you ever used primary scientific literature (published original scientific articles) with undergraduate students?
2. Have you used primary scientific literature with undergraduate students in the last two academic years?
3. In the last two academic years, have you used primary scientific literature with undergraduates in a journal club?
4. In the last two academic years, have you used primary scientific literature in an undergraduate course that is not a journal club?
5. What is the typical size of course (not including journal clubs) in which you have used primary scientific literature?
6. Approximately how many articles were used with students?
7. Approximately how much time in the quarter or semester did students spend on article material and related activities in class?
8. Approximately how much time in the quarter or semester were students expected to spend on article material and related activities outside of class?
9. Within the university or institution, is that course considered to be upper level or lower level?
10. Which of the following best reflects your role in the decision to use primary scientific literature in that course?

Once participants answered questions 1-5, they were then asked to consider a single course in a given category (less than or equal to 25 students, 25-75 students, greater than or equal to 75 students) for the remaining questions.

C. Reasons for using primary scientific literature

Please provide reasoning for why you used primary scientific literature in that course. If you did not have a role in deciding whether to use articles in that course, please describe and/or select your understanding of why primary scientific article(s) were used in that course. Choose all that apply.

To measure reasons for using primary scientific literature in undergraduate courses, I developed a fifteen-item inventory. Items were created from a review of studies that report on the use of primary scientific literature in the undergraduate classroom.

Participants could select all that apply. Participants were also able to respond in an open-ended format. Open-ended responses for this questions were also coded using content analysis and grounded theory. I coded forty two open-ended responses into three categories and twelve sub-categories. Three salient themes emerged from the data (Figure 6), including aspirations for student skills/gains (22 instances), descriptions of articles as representative (21 instances), and exposure (21 instances). *Aspirations for student skills/gains* includes six subcategories: understanding of material, understanding of language used in articles, acquired authentic experiences, interpersonal gains, ability to evaluate claims, and future preparedness. *Descriptions of articles as representative* includes the three subcategories: articles as representing the process of science, articles as representing that which is real, valid, or authentic, and articles as representative of something essential and significant to science. *Exposure* includes three sub-categories: exposure to topics, exposure to the primary scientific literature, and exposure to elements of the scientific process

D. Reasons for not using primary scientific literature

I included questions in the survey to gauge reported barriers towards using primary scientific literature in the undergraduate classroom. This question was available in two formats. Participants who reported that they *do* use primary scientific literature were eventually routed to the following question: *Consider your experience teaching undergraduate courses in which you have not used primary scientific literature. Why did you not use articles in those course(s)? Choose all that apply*. Participants who reported that they *did not* use primary scientific literature in undergraduate courses in the last two years were routed to the following question: *What are some reasons you can cite for not using primary scientific articles with undergraduate students? Choose all that apply*. Responses from both variations of the question were pooled together in the results.

Participants could choose all that apply from an 11-item inventory. Items were again created from a review of studies that report on the use of primary scientific literature in the undergraduate classroom. Participants could also select "other" and provide their own reasoning for not using primary scientific literature in undergraduate courses. Of the fifteen open-ended responses that were provided, two clear themes emerged: 1) the course is too large or 2) they use primary scientific literature in all of courses. These items were added as additional categories to compare to the items provided on the original 11-item inventory. "Other" in the results (Figure 7) has been modified to reflect three of the fifteen open-ended responses, as well as items from the 11-item inventory that received three or fewer responses.

E. Activities using primary scientific articles

When using primary scientific literature in that course, what did you have students do?

Participants could select from an eighteen-item inventory that contained various statements about what activities students completed in the classroom. Items were again created from a review of studies that report on the use of primary scientific literature in the undergraduate classroom. The final eighteen items were selected to reflect concrete actions that students were possibly completing with article material. Participants could also respond to an additional and optional open-ended response question, in which they could elaborate or extend on those activities that they have students complete.

Completed open-ended responses (32) were again analyzed using content analysis and grounded theory. Responses on the 18-item inventory were also coded by themes. Four of the eighteen items from the original 18-item inventory were not included in the analysis. These items were not included in the analysis for the following reasons: 1) possible ambiguity and repetition with other items, 2) no participant selected that item as the only activity they had students complete and 3) very low response rate.

Four items were binned together to create the category "analyze specific section" and three items were binned together to create the category "summarization". This did not necessarily mean that they were equally comparable, only that they reflected similar activities. I then averaged the number of responses for items in each of those two categories in order to present those data with results (Figure 8) from the original inventory.

F. Evaluation of student gains or outcomes

In that course, did you, or anyone else, evaluate student gains from their experiences with primary scientific articles?

This question was developed to measure whether or not instructors evaluated student gains or outcomes from their experiences with this specific type of material (articles) or from specific activities relating to the material.

CHAPTER 3

RESULTS

The majority of participants reported as being professors (62), while five respondents reported being lecturers or instructors, and one participant reported being a research scientist. The majority of participants reported their race or ethnicity as White (88%), 4% as Other, 3% as Latina or Latino, and 1% as Middle Eastern. Almost half of participants reported teaching undergraduate students for more than twenty years (Table 1). Ninety-seven percent of respondents reported as being an author on at least one primary scientific article. Sixty percent of respondents reported that they were currently conducting research.

Table 1. Number of years teaching undergraduates

Less than one year	1.52%	1
1-3 years	10.61%	7
4-10 years	25.76%	17
11-15 years	13.64%	9
16-20 years	6.06%	4
More than 20 years	42.42%	28

A. Representation

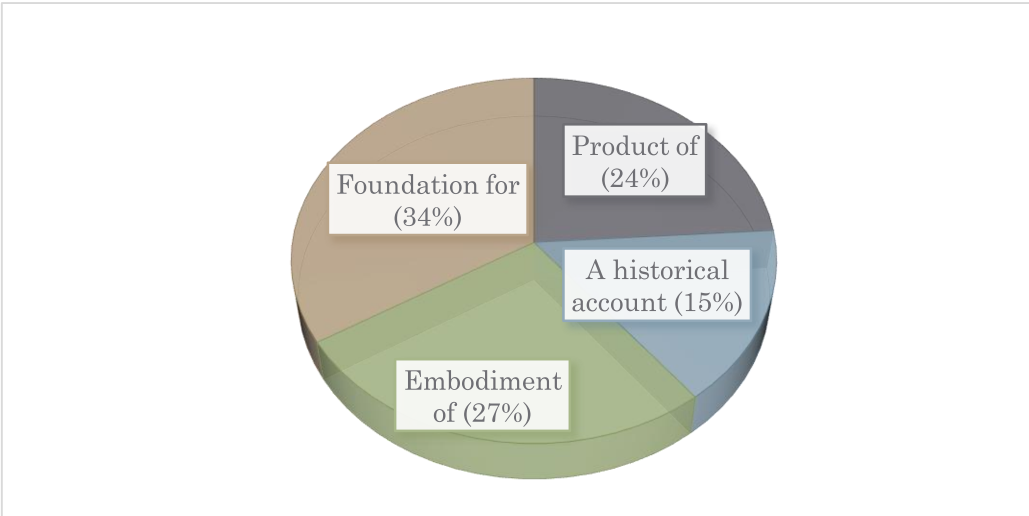

Figure 1. *As someone who has published article(s), what does the body of scientific literature represent to you?* Figure represents emergent themes from open-ended responses (71 occurrences in 57 responses)

Table 2. Scientific literature representation: categories and example phrases

Product of	**A historical account**	**Embodiment of**	**Foundation for**
A lot of work by a lot of people :-)	The whole body of scientific literature is an unfolding history of the way we learn about the natural world as well as what we have recorded about what we have learned.	The freshest embodiment of scientific argument and progress aside from actually working in a lab (or on a research project more broadly).	Something upon which scientific inquiry builds upon.
It is also the net product of whatever social and political factors influenced what we have studied over the years,	The accumulated knowledge of generations of scientists.	Scientific knowledge itself	The basis for asking new questions
Shared principles of evaluating scientific evidence in light of falsifiable hypotheses.	It is a repository of what we know about the world and how that knowledge was obtained that would be lost otherwise.	The "open source" nature of science - we share so that the field can move forward more quickly and to ensure that our results are vetted broadly.	How scientific knowledge is gained and what is the level of evidence for the conclusion
The continually developing state of understanding of biology.	The past and current state of scientific knowledge, the actual findings as they were originally published	The core of scientific thought in the field. Science is a living body and it is reflected in the primary literature.	Knowledge of the natural world that informs human activity
The evolution of the questioning human mind about how things work	It provides an historical record of the field.	Current research, new techniques and discoveries, identification of and solutions to problems.	A scientist can determine what questions are interesting but not yet answered. Thus, the primary literature can be a guide to future study.
Rigorous (mostly) documentation of objective reality	A wealth of accomplishment and a history of knowledge and inquiry.	As a whole, it is our corpus of scientific knowledge.	Provide an access point to our research for those less experienced and looking to learn more about a specific topic or research in general.
As the primary product of scientific efforts	It represents the historical development and current state of knowledge for each of the topics addressed	Science	The development of new hypotheses - the foundation of our science education in the US.

B. Practices

Sixty-six respondents (97%) reported using primary scientific literature in undergraduate courses at some point in their academic careers. Sixty one respondents reported using primary scientific literature in undergraduate courses *in the last two years.* Of the sixty-one respondents who have used primary scientific literature in the last two years, sixty reported using primary scientific literature in an undergraduate lecture or lab course *that is not a journal club.* Twenty-seven respondents also reported using primary scientific literature in both lecture and labs, as well as in journal clubs or similar. Respondents who use primary scientific literature in lecture or lab courses that are not journal clubs were further asked to describe the typical course in which they were using primary scientific literature (Figure 2). Fifty eight of sixty participants responded. Participants who responded as "other" and provided detail often noted that they typically taught using primary scientific literature *in more than one type of course.* All participants reported that they personally, or in collaboration with a co-instructor, chose to use primary scientific literature in a given course.

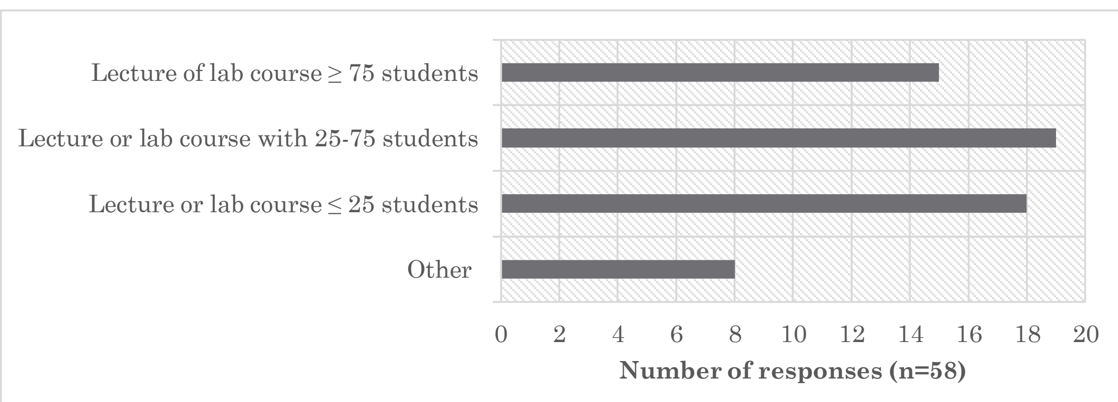

Figure 2. Typical course in which respondents use primary scientific literature (not including journal clubs)

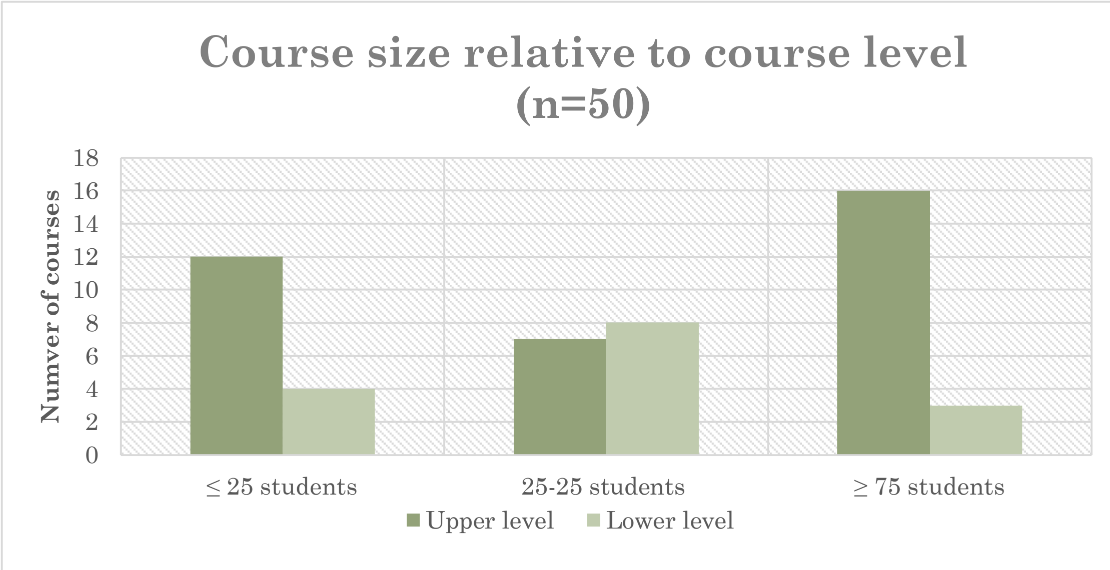

Figure 3. Distribution of course level (upper or lower) relative to course size. Participants were asked to consider one course in a given category (≤ 25 students, 25-75 students, ≥ 75 students)

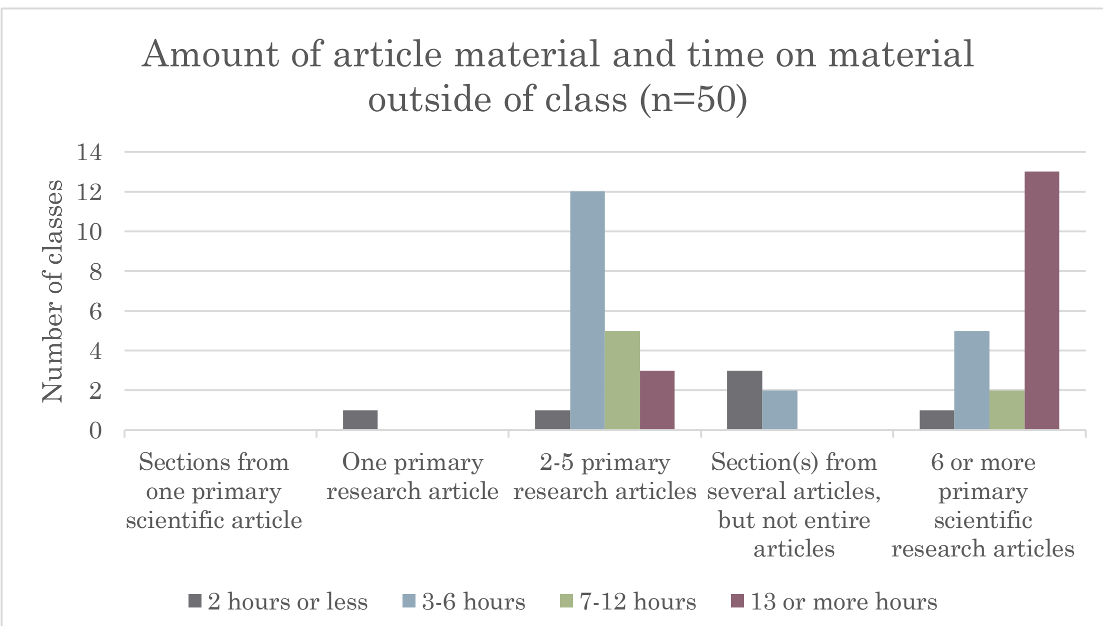

Figure 4. Distribution of the amount of article material and the amount of time students were expected to spend on article material outside of class over the course of the quarter or semester

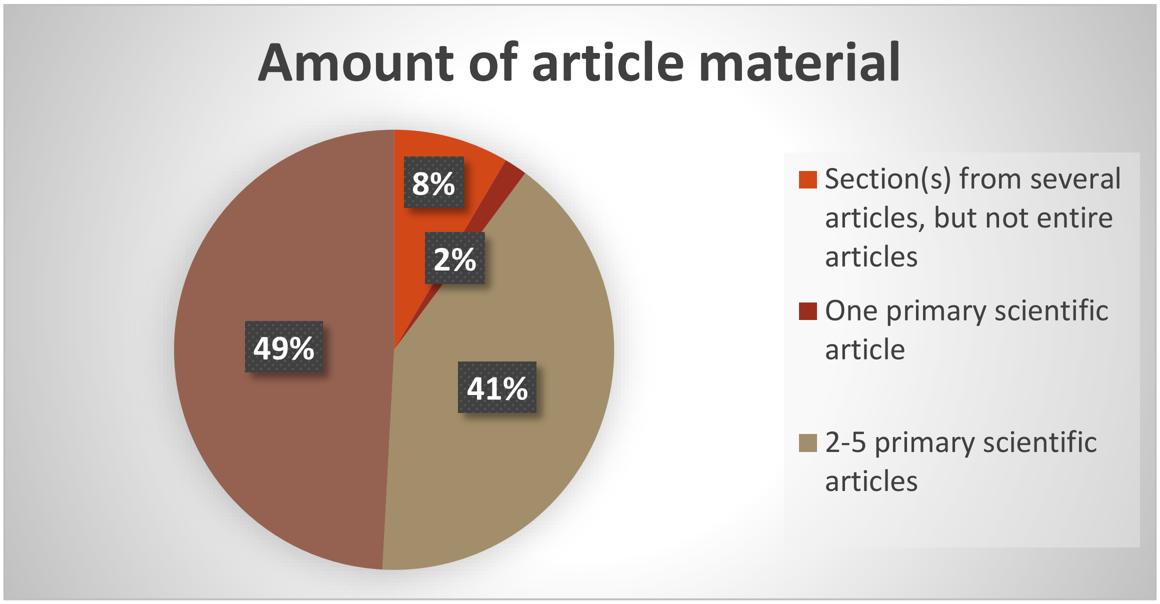

Figure 5. Distribution of the amount of article material used in that undergraduate course

C. Reasons for using primary scientific literature

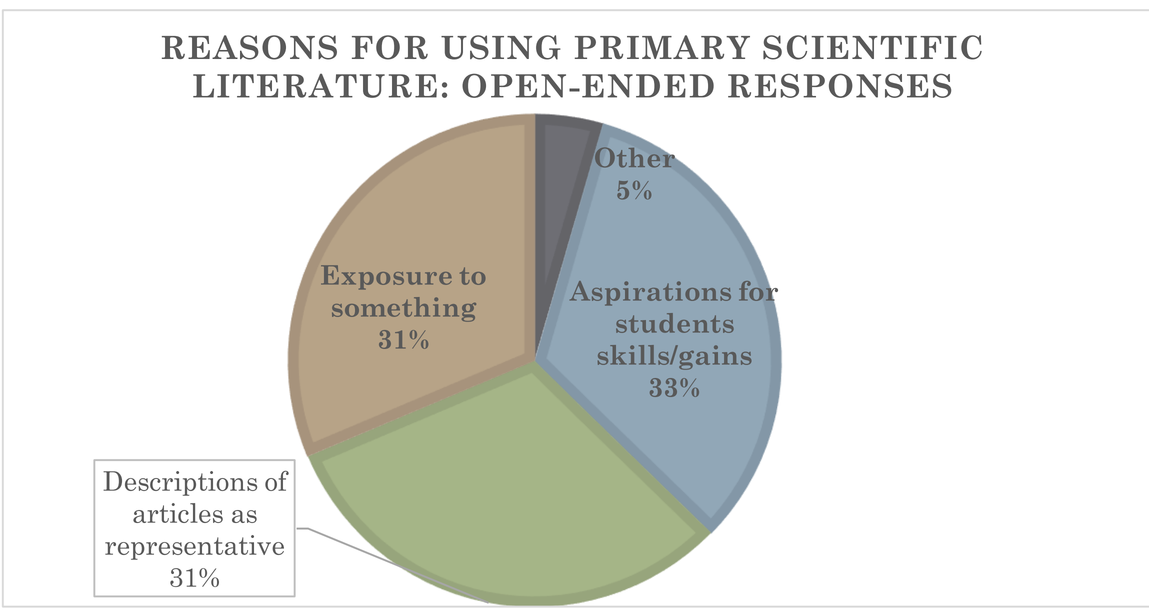

Figure 6. Categorical responses (n=67) for open-ended responses. Forty-two responses were coded to reflect three major categories and 12 sub-categories. Multiple items coded for more than one category. See Appendix B for representative quotes from given categories

Table 3. Frequency of responses for five most selected categories (out of 15 total categories)	
Why did you use primary scientific literature in that undergraduate course setting?	**Frequency of responses**
Familiarize students with scientific literature	53
Familiarize students with how scientific knowledge is generated	51
Improve student' critical analysis skills	47
Familiarize students with how research is conducted	44
Increase students' understanding of experimental design	40

D. Reasons for not using primary scientific literature in undergraduate course settings

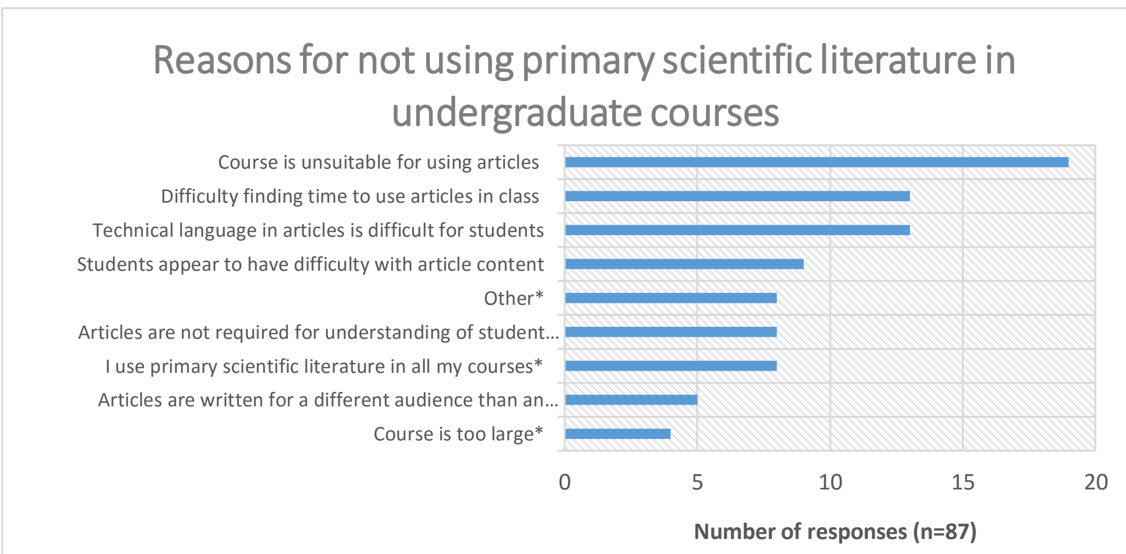

Figure 7. *What are reasons you can cite for not using primary scientific literature in undergraduate courses?* Participants had the option to choose all that apply. 87 total responses. *Categories provided in free response by respondents.

E. Activities students completed with article material

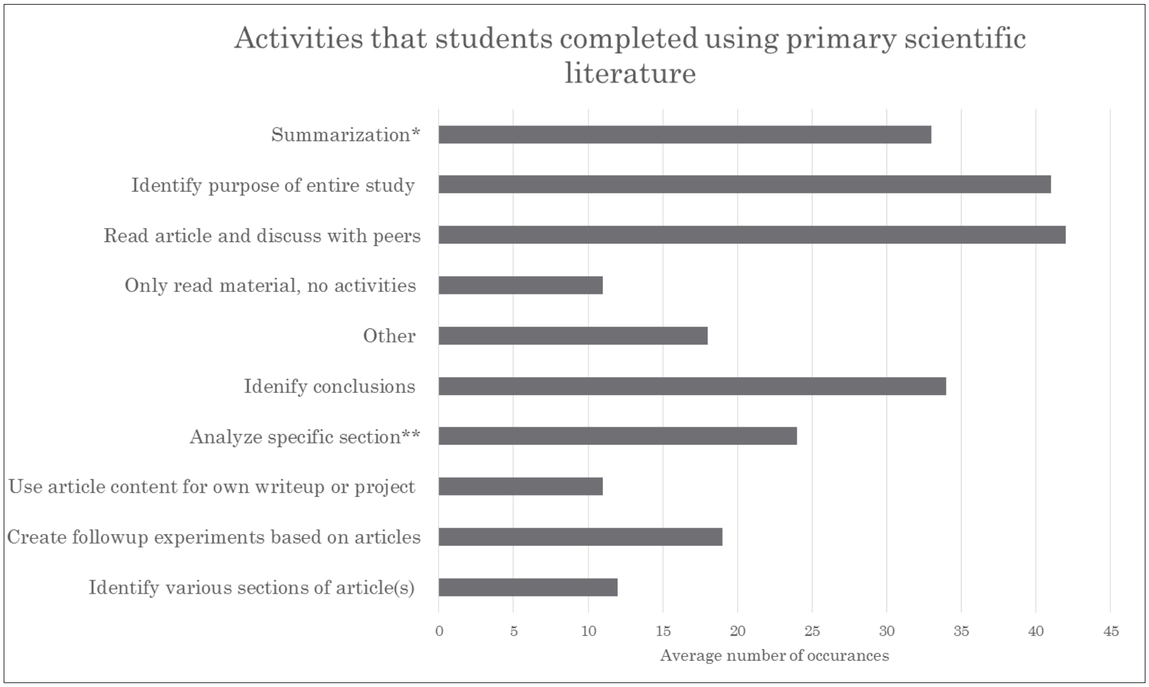

Figure 8. When using primary scientific literature in that course, what did you have students do? Average number of responses for given categories. Respondents could select all that applied. *Average for three categories classified as summarization. **Average for four categories classified as analysis of specific sections of article

Several new themes were identified from coding open-ended responses, including students presentations, complementary papers, develop own research, demonstrate understanding of article content, and learn "how to". The majority of open-ended responses coded to reflect some of the themes provided in the multi-item inventory; particularly *summarization* and *use article content for own write up or project.*

Table 4. New themes from open-ended responses on activities students completed	
Presentation	"1 page synopsis of journal article s and presentations of articles for the class."
	"Select students would help lead discussion (along with me)…each group summarizing either intro, methods, results or discussion."

Complementary papers	"It is based on reading a series of classic research articles presented in historical sequence relating to a specific theme."
	"Identify significant articles in a stream of discovery of a story."
Develop own research project	"Identified principles of experimental design that could be used as models for their own final projects."
	"Design of original study."
Demonstrate understanding of article content	"Reading quiz: students read a paper, then within a one hour period have to answer ten comprehensive questions. This is done online as a homework."
	"I usually provide a summary of the article's idea, then ask the students clicker questions which relate those ideas to what is current practice in diagnostic laboratory testing."
Learn "how to"	"Students had to fill out a 'Navigating a Scientific Paper' worksheet to help them learn how to read a scientific paper."
	"Students learn to ready[sic] any primary literature."

F. Evaluation of student outcomes

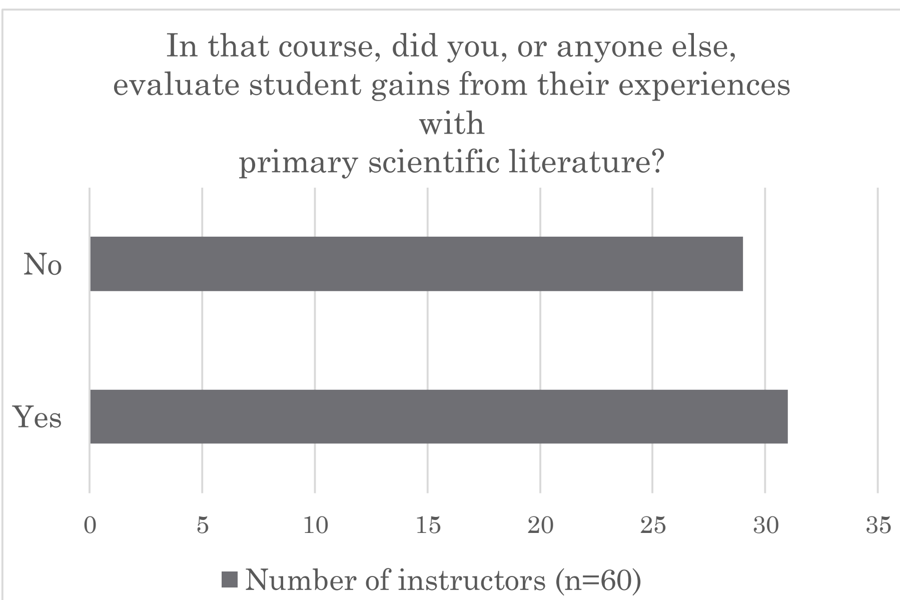

Figure 9. Distribution of responses on whether or not student gains were measured

CHAPTER 4

DISCUSSION

For this project, I considered faculty demographics and their views of the body of scientific literature as possible factors in affecting how and why they use primary scientific literature in the classroom. All participants, save perhaps the several who identified as Instructor/Lecturer, probably hold a doctorate degree and are affiliated with institutions classified as very high research. Faculty at very high research institutions are integrated into systems that help nurture strong researcher identities. These institutions have developed and maintained research identities by the quality and quantity of their publications and contributions towards innovation, as well as by obtaining and maintaining significant funding for research (Geiger 1993; Carnegie Foundation 2011). New and incoming scholars are then integrated into the already established traditions of research. While the identity of faculty members as researchers may be salient to faculty as an emblem of professional attainment, it is also reflective of a merit-based system in which production and publication from research are rewarded (Brusa et al. 2010; Alexandria 2011). In these systems, the faculty identity of "instructor" may hold less value than that of "researcher" (Brownell & Tanner 2012). Arguably, the driving factor behind more or less association with each identity may be the system itself, and the disproportionate merit placed on instructor competency vs researcher competency (Amara 2015). In completing this study I was less concerned with differences in the value that faculty place on instruction vs. research I took into consideration the potential for changes in teaching styles and choice of classroom material, based on instructor co-identities, such as “researcher”.

A component of being engrained into a system such as a research university includes adoption into a collective group of like-minded individuals. Within the scientific community, in particular, similarities in practices and procedures help to define it as a community of practice (Brown & Duguid 1991). Within this community, communicating scientific findings is arguably synonymous with practicing science. Writing about the process is fundamentally a byproduct of doing science. Indeed over 60% of individuals who responded reported that they are currently conducting research and 97% reported as being an author on at least one primary research article. This indicates that these individuals are more likely to be engaged in the community of practice of research scientists.

A certain proportion (27%) of responses regarding what the body of scientific literature represents were coded to reflect this notion of the primary scientific literature as being the “embodiment of” something, perhaps within this community. Though these responses could be merely a reflection of the way in which the question was asked; what does the body of primary scientific literature *represent,* the particular responses given were insightful. Several participants gave single-word responses, such as “Science” and “Knowledge”. These responses seemed to indicate that the body of primary scientific literature represents something less concrete and yet fundamentally more significant than simply a collection of papers or content.

The emergent category of “foundation for” represented various statements that aligned with perceived and actual utility of the body of work. There were several themes within the category of “foundation for” that seemed to identify two pathways for how this body of material may be instrumental: respondents who cited the literature as a foundation for designing subsequent research within their own fields and respondents who cited the literature as being a foundation for how *anyone* could acquire knowledge. Those answers that align with the first pathway (use for subsequent researcher questions in the field) seem reflective of the respondent’s own community, in which information about what we know and how we know it comes directly from this body of literature. Those answers following the second pathway (use for anyone gaining knowledge more broadly) seem to represent a different approach to the original question. Those individuals may have identified the accumulation of written scientific findings, observations, and their dissemination *as directly informing all other sources of information.* This particular framework or pathway may make sense to people who utilize this material to inform their own work. However, it seems less likely that someone outside the community of scholars would immediately identify the relationship between a corpus of articles and the production of knowledge. Student populations, particularly at the introductory level, are arguably less exposed to the original source material in general and may not necessarily make these same connections.

The emergent category of “product of” is potentially indicative of the association those respondents have as direct contributors to that body of work. These type of responses situate the respondent within the knowledge-making process. Several responses also seem to indicate that the body of literature is the product not only of people contributing and completing the work along the way, but as a product of the human capacity to seek understanding about those things that we don't understand. There are differences between "it is a collection of information" and "it is a collection of information *that people worked to create*". The difference being that this collection of work cannot exist without consideration for how and why it came to be in the first place. Namely, that people were and have been experimenting, collaborating, and communicating about science and that this corpus is an artifact of that process. This theme is perhaps also reflective in those responses that aligned with the category of "a historical account." The responses on what the primary literature represents allude to this idea that faculty members are reinforced into thinking about research and its publications or the larger body of literature as something with a rich history, substantial value, and tangible utility. Faculty perceptions of the literature itself may be informing how and why they utilize it in undergraduate classrooms.

In terms of *why*, we can look at responses from the closed-ended inventory as well as open-ended responses. The coded open-ended responses showed an almost equal distribution into the three different categories; aspirations for student skills/gains (22 instances), descriptions of articles as representative (21 instances), and exposure (21 instances). Only one-third of open-ended responses were coded to reflect aspirations of student skills/gains. The caveat of these claims is that I cannot know for sure that instructors whose responses fell into the other two categories *did not* utilize the material with the intention of increasing student skills. However, responses that contained descriptions around “exposure” and “descriptions of articles as representative” were categorized as so based on explicit language that did not reflect any tangible student gains or skills. These data may reflect a decision to utilize material only in an attempt to simply introduce, or expose students to the material itself, as opposed to teach students tangible skills, or even science content.

Those responses from the original multi-item inventory are interesting so far as to show the diversity and range of reasons for why these instructors may be using primary literature with students. Unfortunately, the categories are somewhat vague. For example, “familiarize students with how scientific knowledge is generated” could mean something different to different individuals. However, the interesting part of the analysis from data on reasoning for using primary scientific literature is the frequency at which respondents selected some of these items on the multi-item inventory and how those responses correlate with the activities students did. Participants responded with higher frequency to “familiarize students with how scientific knowledge is generated” than the item of “increase students understanding of experimental design.” Without more analysis, or a more in-depth discussion, I can’t know for sure what respondents meant by selecting these items. However, I argue that, according to the types of activities that faculty report having actually have students do, faculty may have reasoning that *did not translate into student activities or outcomes.*

The four categories that instructors were more likely to prompt students to complete with article material included summarization-type activities, read articles with peers, and identify both the purpose of the entire study and the conclusions. They were least likely to select the categories of read material only with no further activities, and least likely to have students use article content for their own write up or experiment. Only several respondents mentioned having students follow a “pathway of discovery”. By proxy of having students write up their own work or project based on the content of several articles, students may or may not have been introduced to the construct of a “pathway of discovery” in their own way. Yet, I would argue that students were most likely utilizing articles to inform very specific items in their own work and therefore being overly selective about what types of material they chose to pull from any given article. This approach would not follow the same trajectory as how one instructor framed the activity they reported completing with students: “It is based on reading a series of classic research articles presented in *historical sequence* relating to a specific theme.” This may indicates that though faculty have the intention of demonstrating how scientific “knowledge” is generated, students may be interacting with the material in a way that does not necessarily foster understanding at such a holistic level.

Again though, based on the coding scheme from open-ended responses on *why*, two third of instructors report that their intentions are to simply *expose students to the material* or *demonstrate how the material is representative of something.* Only one third of responses were coded with the reason for using primary scientific literature as *aspirations for tangible student skills/gains.* That is not to say that faculty aren't using primary scientific literature to simply inform the content they teach. Only that we've identified something interesting about other reasons for using it. The survey was also designed to reflect lecture or lab courses and not journal clubs. Journal clubs arguably exist as a means to focus on an accumulation of papers and findings around a certain topic. All of the courses that were discussed in this analysis were reported as being non-journal club settings. Therefore, these data reflect an instructor-decision to use this material in classes that focus on other content.

These data also show that almost half of respondent *did not* measure student outcomes or gains from their experiences with primary scientific literature. Several participants who did measure outcomes or gains provided open-ended responses in regards to what they did for evaluation. Open-ended responses fell into several categories; students were "evaluated" based on some sort of output, such as a paper or project, or students provided feedback in the form of a course evaluation, module evaluation. Only one participant alluded to an evaluation technique in which students were asked describe and analyze their specific experience with primary scientific literature. Though we do not formally evaluate all student experiences, one could argue that both educators and students benefit from understanding the impact of different classroom practices on student outcomes.

Conclusions:

What started as the rigorous documentation of work, to be scrutinized by the "collective body of scientists" and then inform new research (Vickery 2000), has developed into a corpus of conclusions about the living world that both experts and non-experts, such as students, can now access. Because of this phenomenon, publications in science reflect claims about the world, with no easily identifiable indication of failures along the way. The end product being a concise and polished product that a non-expert, such as a student, may not feel the need to critically evaluate before accepting into their knowledge base. Van Lacum et al. (2014) found that students in undergraduate science courses were inclined to disregard methods sections of articles and had difficulty identifying limitations or counterarguments, even when directed to do so. The authors argue that identifying or conceiving of limitations and counterarguments is difficult for students, because of the persuasive way in which authors of research articles present their conclusions and results. Also, the authors argue that students are traditionally taught via textbooks and not given information about *how scientific claims come to be*. Therefore, students are not really given the opportunity to think critically about the process by which scientific facts or "knowledge" emerged. When given without context of history and previous research, commentary and reviews by experts in the field, concurrent research, and without consideration for replication and future research, primary research articles do nothing more than present students with a simple, clean, science claim to add to their existing base of science content. It has to be noted that we do not know for sure that these faculty or faculty in general aren't stressing the overall context surround primary scientific literature. We simply need more information in this area. We didn't collect information on explicit course objectives, which may have been more indicative of "reasoning" than the way in which we collected data on reasoning. It would be insightful to find out whether there were explicit course objectives for that material. Presumably, we introduce activities or modules into a class with the intention of having students gain something from this. How could we know what students are gaining if we're not measuring anything in the first place?

Arguably, the significance of a given item, such as primary scientific literature, may only be a reflection of its perceived utility. This type of material is viewed as fundamentally significant to a community of practice in science. I have argued that how that material is used in the classroom may be indicative of faculty members' own association with a community of practice. However, that utility may be less significant or be shaped differently, based on how the material is presented in the classroom and subsequently, how students view the utility and value of that material. With certain populations of undergraduates, that utility may only come if the form of picking talking points out of this literature to inform their own write-ups, which are often "research papers" focused on accumulating or summarizing facts about something we already know.

While one may argue that any exposure at all is good for students, faculty may have unsubstantiated perceptions of what their students are getting out of experiences with these articles, due largely to their own affiliations and utility of the material. We may be missing out on an opportunity to teach students more about certain elements in the "process of science"; creating knowledge, questioning prior claims, testing hypotheses, uncertainty (as reported by faculty in their perceptions of what the literature represents) when we limit student interactions to mere summarizations of an article or two. We may also be contributing to misconceptions about what it takes to "do science", if indeed that is what we're attempting to teach students. A single article, or several disconnected articles are arguably not representative of the process of science as being based on all previous works, failures, and contributions by a certain community of practice (once again, as identified in participant responses of what the literature represents).

We can say that many of these faculty seem to be using primary scientific literature to introduce students to something that they, as a researcher and as a member of the community of practice in science, see in and of itself as being highly significant. They may be expecting students to gain some understanding of the material that may or may not be measurable-whether it be a lack of survey instruments to do so, or whether it because this form of knowledge is difficult to express and quantify. The next set of questions become, but how do students view and utilize this material? How do we mitigate differences in our perceived significance and utility of the material with how we present it and use it with a population that is not yet, or may never become research scientists?

CHAPTER 5

LIMITATIONS

The data from this study depend solely on self-report, so the data may not represent what faculty actually have done with undergraduate students. As all data were anonymized immediately after survey completion, there is no way to follow up with participants and clarify results. The data are also based on a relatively small sample size, which limited the amount of analysis we could do. Also, there are certain limitations to developing an online survey. I considered amount of time that participants would be expected to spend on material, as well as the flow logic of various questions. I worked to ensure that questions were answered in a certain order, or that certain questions led to the correct subsequent questions. Because of these considerations, I limited the amount of material that I collected from the survey, to mitigate the possibility of respondents becoming apathetic or fatigued while taking the survey.

As a part of recruitment, the subject heading of the email, as well as the content of the recruitment email itself, contained specific language citing "practices using primary scientific literature." Arguably, only those instructors who had indeed, or at least recently, used primary scientific literature followed up to answer the survey. As a part of the recruitment process, several potential participants emailed to inquire as to whether they should complete the survey. They explicitly noted that they had either not taught undergraduate students for some time, or that they felt that because they taught introductory courses, then their responses would not be interesting. Unfortunately, we may have missed opportunities to collect data from these individuals. The decisions to include specific reference to “primary scientific literature” (in recruitment materials) were made largely to try to mitigate expected low response rates. Though I lack empirical evidence, anecdotally I was concerned that faculty would not respond to a survey without being provided with a general subject area. Participants were also selected from what qualitative researchers may consider to be an “elite” population (Marshall and Rossman 2006). Outcomes of working with elite populations may be dependent on whether there are perceived threats to an individual’s status or integrity. Also, the recruitment email was solicited as asking potential participants to share their teaching practices. Those participants who may not see “instructor” as a salient identity may have been less likely to want to expand on their teaching practices.

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APPENDIX A
SURVEY QUESTIONS

Survey Questions:
NOTE: open-ended questions marked as <Open-ended>

Have you taught an undergraduate course within the last two academic years?
- ❍ Yes (1)
- ❍ No (2)

Approximately how many years of experience do you have teaching undergraduates students?
- ❍ Less than one year (1)
- ❍ 1-3 years (2)
- ❍ 4-10 years (3)
- ❍ 11-15 years (4)
- ❍ 16-20 years (5)
- ❍ More than 20 years (6)

About how many students are in undergraduate courses that you teach? If you teach different types of courses, please choose all that apply.
- ❑ 20 or less (1)
- ❑ 21-50 (2)
- ❑ 51-100 (3)
- ❑ 101-200 (4)
- ❑ 201-350 (5)
- ❑ 350 or more (6)

In the time that you have taught undergraduate courses, have you ever used primary scientific literature (published scientific articles) with undergraduate students?
- ❍ Yes (1)
- ❍ No (2)

Have you used primary scientific literature with undergraduate students in the last two academic years?
- ❍ Yes (1)
- ❍ No (2)

In the last two academic years, have you used primary scientific literature with undergraduates in a journal club?
- ❑ Yes (1)
- ❑ No (4)

In the last two academic years, have you used primary scientific literature in an undergraduate course that is not a journal club?
- ❍ Yes (1)
- ❍ No (2)

In the last two academic years, what is the typical size of lecture or lab courses (not including journal clubs) in which you have used primary scientific literature?
- ❍ Lecture or lab course with more than 75 students (1)
- ❍ Lecture or lab course with 25-75 students (3)
- ❍ Lecture or lab course with less than 25 students (4)
- ❍ Other: (2) ____________________

Consider one journal club in which you have used primary scientific literature. Approximately how many students were in the journal club?
- ❍ 10 or less (1)
- ❍ 11-20 (5)
- ❍ 21-50 (2)
- ❍ 51-100 (3)
- ❍ Other: (4) ____________________

Approximately how many articles were used with students?
- ❍ Section(s) from one article, but not an entire article (1)
- ❍ Sections(s) from several articles, but not entire articles (4)
- ❍ One primary scientific article (2)
- ❍ 2-5 primary scientific articles (3)
- ❍ 6 or more primary scientific articles (5)

Approximately how many students were in that course/undergraduate setting?
- ❍ 20 or less (1)
- ❍ 21-50 (2)
- ❍ 51-100 (3)
- ❍ Other: (4) ____________________

Approximately how many articles were used with students?
- ❍ Section(s) from one article, but not an entire article (1)
- ❍ Sections(s) from several articles, but not entire articles (4)
- ❍ One primary scientific article (2)
- ❍ Two or more primary scientific articles (3)

Consider one undergraduate lecture or lab course with 25-75 students in which you have used primary scientific literature. Approximately how many articles were used with students?

- ❍ Section(s) from one article, but not an entire article (1)
- ❍ Section(s) from several articles, but not entire articles (4)
- ❍ One primary scientific article (2)
- ❍ Two or more primary scientific articles (3)

Consider one undergraduate lecture or lab course with more than 75 students in which you have used primary scientific literature. Approximately how many articles were used with students?

- ❍ Section(s) from one article, but not an entire article (1)
- ❍ Section(s) from several articles, but not entire articles (4)
- ❍ One primary scientific article (2)
- ❍ Two or more primary scientific articles (3)

Consider one undergraduate lecture or lab course with less than 25 students in which you have used primary scientific literature. Approximately how many articles were used with students?

- ❍ Section(s) from one article, but not an entire article (1)
- ❍ Section(s) from several articles, but not entire articles (4)
- ❍ One primary scientific article (2)
- ❍ Two or more primary scientific articles (3)

Consider the same course. Approximately how much time did students spend on article material and related activities in class?

- ❍ One class period or less (1)
- ❍ 1-3 class periods (2)
- ❍ 4-8 class periods (3)
- ❍ 9-12 class periods (4)
- ❍ Students completed all work outside of scheduled class (6)
- ❍ Other (5) ____________________

Approximately how much time were students expected to spend on article material and related activities outside of class?

- ❍ 2 hours or less (1)
- ❍ 3-6 hours (2)
- ❍ 6 or more hours (3)
- ❍ Other (4) ____________________

When using primary scientific literature in that course, what did you have students do? Choose all that apply.

- ❑ Students were introduced to article material, but did not complete specific activities (18)
- ❑ Read article and review in class with instructor (1)
- ❑ Read article and discuss with peers (2)
- ❑ Read background/literature review in article (3)
- ❑ Read article and provide a summary (5)
- ❑ Summarize experimental design (14)
- ❑ Summarize conclusion(s) (15)
- ❑ Identify purpose of the study (4)
- ❑ Identify persuasive or argumentative language (10)
- ❑ Identify various sections of the article(s) (6)
- ❑ Identify conclusion(s) (11)
- ❑ Create potential follow-up experiment(s) after reviewing article(s) (7)
- ❑ Compose own article or similar (8)
- ❑ Analyze method(s) (12)
- ❑ Analyze limitations (9)
- ❑ Analyze figure(s) and/or table(s) (13)
- ❑ Analyze conclusion(s) (16)
- ❑ Review references (17)
- ❑ None of the above (36)

<Open-ended> Please describe any additional activities that students in that course completed with primary scientific literature.

Which of the following best reflects your role in the decision to use primary scientific literature in that course?

- ❍ I personally decided to use primary scientific literature in that course (1)
- ❍ I, along with a collaborator or team, decided to use primary scientific literature in that course (2)
- ❍ A supervisor or overseeing instructor decided that primary scientific literature should be used in that course (3)
- ❍ A committee or department decided that primary scientific literature should be used in that course (4)
- ❍ Other (5) ____________________

Within the university or institution, is the course considered to be upper level or lower level?

- ❍ Upper level (1)
- ❍ Lower level (2)

In that course, did you, or anyone else, evaluate student gains from their experiences with primary scientific literature?

- ❍ Yes (1)
- ❍ No (2)

<Open-ended> Please describe any techniques used to evaluate student gains from their experiences with primary scientific literature.

Why did you use primary scientific literature in that course? If you did not have a role in deciding whether to use articles in that course, please describe and/or select your understanding of why primary scientific article(s) were used in that course. Choose all that apply.

- ❑ Not sure (17)
- ❑ Connect textbook and/or course content to published scientific research article (8)
- ❑ Familiarize students with how scientific knowledge is generated (1)
- ❑ Familiarize students with scientific communication process (15)
- ❑ Familiarize students with scientific literature (9)
- ❑ Familiarize students with questions and concepts that guide scientific investigations (3)
- ❑ Familiarize students with how research is conducted (11)
- ❑ Provide more context for course material (12)
- ❑ Provide an example of how primary scientific literature differs from other sources of information (2)
- ❑ Demonstrate the use of persuasive or argumentative language in articles (4)
- ❑ Demonstrate the layout and format of an article (5)
- ❑ Increase students' understanding of methods and results (6)
- ❑ Increase students' understanding of experimental design (7)
- ❑ Increase students' understanding of figures and tables (10)
- ❑ Improve students' critical analysis skills (13)
- ❑ Increase students' understanding of a particular science concept (14)
- ❑ None of the above (16)

<Open-ended> Please provide any additional reasoning for why you used primary scientific literature in that course, or any undergraduate course.

Consider your experience teaching undergraduate courses in which you have not used primary scientific literature. Why did you not use articles in those course(s)? Choose all that apply.

- ❑ Course is unsuitable for using articles (4)
- ❑ Technical language in articles is difficult for students (5)
- ❑ Articles are written for a different audience than an undergraduate student (6)
- ❑ Articles are not required for student understanding of course content (7)
- ❑ Difficulty finding time to use articles in class (1)
- ❑ Difficulty in aligning relevant articles with course content (8)
- ❑ Difficulty teaching critical analysis techniques (3)
- ❑ Difficulty in creating activities to go with articles (9)
- ❑ Students appear to be disinterested (2)
- ❑ Students appear to have difficulty with article content (10)
- ❑ Other (Please describe) (11) ____________________
- ❑ None of the above (12)

What are some reasons you can cite for not using primary scientific articles with undergraduate students within the last two academic years? Choose all that apply.

- ❑ I do not have a role in designing course curriculum (12)
- ❑ Course(s) were unsuitable for using articles (4)
- ❑ Technical language in articles is difficult for students (5)
- ❑ Difficulty finding time to use articles in class (1)
- ❑ Difficulty teaching critical analysis techniques (3)
- ❑ Difficulty in aligning relevant articles with course content (8)
- ❑ Difficulty in creating activities to go with articles (9)
- ❑ Articles are written for a different audience than an undergraduate student (6)
- ❑ Articles are not required for student understanding of course content (7)
- ❑ Students appear to be disinterested (2)
- ❑ Students appear to have difficulty with article content (10)
- ❑ Other (Please describe) (11) ____________________
- ❑ None of the above (24)

What are some reasons you can cite for not using primary scientific articles with undergraduate students? Choose all that apply.

- ❑ I do not have a role in designing course curriculum (12)
- ❑ Course(s) were unsuitable for using articles (4)
- ❑ Technical language in articles is difficult for students (5)
- ❑ Difficulty finding time to use articles in class (1)
- ❑ Difficulty teaching critical analysis techniques (3)
- ❑ Difficulty in aligning relevant articles with course content (8)
- ❑ Difficulty in creating activities to go with articles (9)
- ❑ Articles are written for a different audience than an undergraduate student (6)
- ❑ Articles are not required for student understanding of course content (7)
- ❑ Students appear to be disinterested (2)
- ❑ Students appear to have difficulty with article content (10)
- ❑ Other (Please describe) (11) ____________________
- ❑ None of the above (24)

Are you currently conducting scientific research at your institution?
- ❍ Yes (1)
- ❍ No (2)

Are you an author on any published primary scientific article(s)?
- ❍ Yes (1)
- ❍ No (2)

<Open-ended> As someone who has published article(s), what does the body of scientific literature represent to you?

<Open-ended> What is your current position?
- ❍ Assistant Professor (1)
- ❍ Associate Professor (2)
- ❍ Graduate Student (3)
- ❍ Lecturer/Instructor (4)
- ❍ Post-doctoral Scholar (8)
- ❍ Professor (5)
- ❍ Other (7) ____________________

<Open-ended> What department are you in?

Which gender do you identify with?
❍ Female (1)
❍ Male (2)
❍ Other (4)
❍ Prefer not to respond (3)

What race or ethnicity do you identify with?
❍ Asian (1)
❍ American Indian (2)
❍ Black or African American (3)
❍ Latina or Latino (4)
❍ White (5)
❍ Other (6)
❍ Prefer not to respond (7)

As a part of this study, we are also conducting optional, follow-up interviews. The follow-up interview would be an opportunity for you to elaborate on your experiences using primary scientific literature in an undergraduate educational setting. If you are interested in competing a follow-up interview, please provide the following contact information:
Name:
Email:
Thank you for your time!

APPENDIX B
REASONS FOR USING PRIMARY SCIENTIFIC LITERATURE: OPEN ENDED RESPONSE

Student skills understanding of language	To understand and interpret the language used in primary literature also.
	Its up to date It gives the students the opportunity to learn to read the literature, to dissect papers, and to understand hypotheses and experiments used to test them.
Student skills understanding of content	Its up to date It gives the students the opportunity to learn to read the literature, to dissect papers, and to understand hypotheses and experiments used to test them.
	genetics is a rapidly changing field the students are in the Honors College and capable of learning directly from the scientific literature
Student skills authentic experiences	To help them generate research ideas for field projects
	Primary scientific literature provides the raison d'etre for understanding science, its premises, procedures, and logical conclusions. It also provides students a way to inform their peers and themselves by presenting original research material in a seminar format.
Student skills intrapersonal	I want students to gain confidence in accessing and understanding primary literature so that they will be more likely to do so in the their future careers (most of which will not be in research).
	Generates more interest in particular topic; Students need exposure to it, how to find what they need, how to tap into the newest/best thinking on a topic
Student skills preparedness	Prepares students for their own careers in academia
	To prepare undergrads for grad school or for employment. Most graduate students, and I assume most students going into the job market, don't know how to read a scientific paper critically and don't know enough about the literature in their area of research.

Exposure topics	Generates more interest in particular topic; Students need exposure to it, how to find what they need, how to tap into the newest/best thinking on a topic
	also to highlight the newest, most exciting findings not yet in textbooks and show science is active process
	Introduce students to new research in the field.
Exposure literature	In a larger format it was just to introduce to the students to what a scientific paper looked like.
	It exposes students to the literature - and to the different types of studies that are out there.
	to introduce students to the primary literature and its critical evaluation. Also to have students learn to translate science to the lay public. to engage students in thinking about how research is done
Expose process	It also seemed important that everyone was exposed at least once to what is involved in generating new knowledge in the natural sciences.
	Students need to understand that our knowledge comes from sharing scientific findings, not from textbooks which merely collate the information and present it in a student-palatable form
	To illustrate uncertainty in science, which isn't found in reports about science.