Student and instructor reactions to the use of historical short stories in a post-secondary introductory biology course.

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Abstract

This study examines the implementation of historically accurate short stories designed for use in introductory post-secondary science courses. The stories describe the development of fundamental science ideas and explicitly draw out nature of science concepts through the use of embedded reflective questions. This mixed methods study investigates student reactions to the short stories and how the short stories affect student interest in pursuing science careers. Additionally, the study investigates how the instructor of the course views the use of historical short stories. Our results indicate that the use of historical short stories in post-secondary introductory biology has positively impacted student interest in science careers and the instructor views the short stories as useful resources to augment their course. Student interest in science careers significantly increased and many students noted surprise or encouragement when writing about new insights on the nature of science such as: science is collaborative, science is creative, and science does not have to be laboratory-based. The instructor intends to continue to use several short stories in their course due to perceived decrease in student resistance to instruction on evolutionary theory and the inclusion of complimentary science content within the short stories.

Introduction

Between 1966 and 1988 the percentage of college freshman with intent to major in science and mathematics decreased by half (Green, 1989). This potential "shortfall" of science workers has had great impact on science education. Some indicate that the

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United States is losing its competitive edge in science and technology (Schmidt *et al*., 1999). These concerns have fueled the flames of the science education crisis, and sent science educators looking for the problems and how to address them.

Most reform efforts have been focused on elementary and secondary education (NRC, 1996; NSTA, 1992; AAAS, 1989). However, Tobias (1990) argues for college science reform:

> The fact is, a very large number of American high school graduates survive their less-than-perfect precollege education with their taste and even some talent for science intact. (p. 8)

While Tobias' call for focus on college is well taken, much can still be learned from studies that address why students opt out of secondary science. Yager and Penick (1984) note that students see science classes as dull, no fun, and a place they do not wish to be. The 1986 NAEP report indicated, "roughly 33% of seventh and eleventh-graders described their science classes as often or always boring" (Weiss, 1993, p. 39).

When Tobias (1990) followed the "second-teir" students she found that students desired to know "*how* the various methods they were learning came to be, *why* physicists and chemists understand nature the way they do, and *what* were the *connections* between what they were learning and the larger world" (p. 81). These students did not opt out of science because they are incapable, but because of lack of interest. Unfortunately, this lack of interest is directed toward classroom science rather than real science. Students seem to desire a more dynamic, creative, and social view of science. These desires mirror accurate views of the nature of science, which has received much attention in the science education literature (Clough & Olson 2004; Matthews 1994; McComas 2004; NRC 1996; McComas, Clough, & Almazroa 1998; Moore 1983; Shamos 1995; Lederman, 1992).

Historically Contextualized Instruction

Historically contextualized science instruction (Stinner et. al., 2003) has been purported to not only enrich student understanding (Jung, 1994; Clough, 2006; Klassen, 2006;), but also enliven the teaching of science (Castro & DeCarvalho, 1995). Also, the use of historical materials can increase student understanding of the nature of science (Irwin, 2000; Solomon et. al., 1996, Brush, 1989). Furthermore, extensive incorporation of historical materials has been shown to increase student understanding of science content (Galili & Hazan, 2000). Perhaps most importantly, Allchin et. al. (1999) have found the use of historical-based laboratory activities to improve student attitudes toward science.

Current Study

As part of an NSF CCLI grant (Clough, Olson, Stanley, Colbert & Cervato, 2006), historically accurate short stories have been developed for use in introductory post-secondary science courses. The stories describe the development of fundamental science ideas and explicitly draw out nature of science concepts through the use of embedded reflective questions. This paper is part of a larger study investigating the affect of these historical short stories on student understanding of both the nature of science and science content.

Research Questions

While the use of historical materials is well supported, the question remains as to what extent the use of such materials increase student interest in pursuing a science career. Additionally, while these materials seem to be useful when implemented effectively, Langer and Applebee (1987) observed how science teachers view new activities in light of their old ways of thinking. This study hopes to address the following questions:

1) To what extent does the inclusion of five historically accurate short stories affect post-secondary student interest in pursuing a science career?
2) How did the instructor view the use of five historically accurate short stories in their post-secondary biology course?

Methods

This study investigated the use of historically accurate short stories in a post-secondary, introductory biology course. While the course is the first biology course for biology majors, others students take the course to fulfill requirements for general studies and for other majors such as chemistry, or pre-med. Topics covered in the course include: diversity of life, classification, genetics and evolution. Short-stories used in the course included: two stories on the age of the Earth, a story on Gregor Mendel, and a story each on both Darwin and Wallace.

To investigate the instructor's views of short story use, one 2-hour interview was conducted to discuss the use of the short stories, the nature of science and how the instructor has been impacted by the story implementation. The interview was transcribed in full and analyzed for themes. The transcript was broken into manageable chunks, read, and open-coded. Open codes were axial coded and grouped into common themes (Strauss & Corbin, 1990). These groups were then read again and analyzed for continuity and possible additional themes.

To understand how the short stories affected student interest in science careers, all students (N = 156) were given an anonymous survey asking about how the stories affected their interest in pursuing a science career. Students responded using a Likert (1 – 5) scale, with five indicating increase in interest and one indicating decrease in interest. Additionally, the students were asked to provide additional comments concerning the short stories.

The student surveys were analyzed using one sample t-tests to test for statistical significant differences from $\mu = 3$ (no change in interest). The student comments were first grouped into three groups based on if they reported decrease in interest, increase in interest or no change in interest in science related careers. Within these groups the student comments were read and placed into more specific categories. The categories

were generated through constant interaction with the data. If a student comment did not fit within a more specific category, a new category was created. The categories were then compared and combined under more broad themes when appropriate. This process resulted in several descriptive themes for each broad level of short story effect on student interest in science careers (decrease, no change, increase).

Results and Discussion

Implementation of short stories.

The five short stories used in this study received "high implementation". The instructor placed significant emphasis on the short stories. Students were given about a week to complete the reading and questions for each short story. During class, the instructor spent significant amounts of time having students discuss their responses to questions in small groups. After small group discussions, the instructor had the students write new insights or questions they had on the back of their assignments. This high level of implementation has been the exception rather than the norm in our experience with short story implementation.

Student interest in science careers

On average, students indicated that the short stories increased their interest in pursuing a science career. The students responded using a Likert scale: five indicating great increase, and one being great decrease, with three indicating that there was no change in the student's interest in pursuing a science career. The mean score (N = 156) was 3.346, which was significantly different from a mean score of three (no change in interest) at greater than the .001 level. While an average difference of 0.346 is not exceptionally large, most students indicated that the short stories had not affect on their interest in a science career (frequencies reported in table 1) and many commented that they were already highly interested in a science career, so the stories did not change their already high interest. Descriptive themes developed from student comments are discussed in greater depth below.

Table 1: Frequency of students' response concerning short story affect on interest in science as a career.

Value	Label	Frequency	Percent
1	Decreased Interest	3	1.9
2		5	3.2
3	No Change	90	57.7
4		51	32.7
5	Increased Interest	7	4.5

The discussion of student comments below is meant to be descriptive in nature. Because of the limited explanation and lack of triangulation, we worked to develop patterns that help organize and describe student views on the stories rather than developing categories to explain student ratings of the stories. The discussion is organized first by student indication of increase, decrease, or no change in interest in science as a career and then sub-themes are explored with reference to actual student comments.

Increased interest in science careers

Many students who indicated that the short stories increased their interest in science as a career and made additional comments indicated that they learned something from the stories. Much of what the students claimed to have learned that increased their interest was closely tied to nature of science understanding.

> [The stories] showed me that science is not only done in a lab which was nice so there are more opportunities.
>
> The cooperation and social aspect of science is something I knew little about, and it makes the career seem much more attractive to me.
>
> It encouraged me to know that scientists work together.
>
> Encouraging to see that science is made up of small contributions.

Other students claimed to have learned something more generally or increased their interest in learning about science.

> [The stories] give me a new insight to issues in science.
>
> I really liked to read them because I learned a lot.
>
> I thought they added a lot of interest to learning about science
>
> Looking forward to learning more.

Some students identified specific topics or individual short stories of interest. Students seemed to enjoy the stories concerning evolution and genetics more than the age of the Earth stories. Perhaps this difference is due to greater perceived connection to course content on the part of the students.

> I was interested in Darwin.
>
> I really enjoyed the Darwin one.
>
> I was interested to read the story of Mendel. That was my favorite.
>
> A couple of the stories increased my interest. I enjoyed evolution and genetics – so those had an impact. The others were extremely boring and almost decreased my interest.

As was more common with students who claimed no change in interest, some students who claimed increased interest noted that their interest in science as a career was already set. For students in the increased interest group, they often noted that the stories added to or reinforced their interest.

> I already have my career field decided, but the stories heightened my interest in science.
>
> I was already interested in science as a career.
>
> I wouldn't say it had a huge impact on my interest in science, but it definitely helped a little.

No change in interest in science careers

A few of the students who indicated that the stories did not affect their interest in science as a career indicated that they did learn from the stories.

> I felt like I gained knowledge, but it had no effect on my interest.
>
> I was already interested so it helped answer questions.
>
> I still want to pursue a career in science regardless of how long the process is.

Most students in this category who left comments noted that they were already interested in science at a high level, so the stories did not affect their interest. Considering this class has a large population of science majors, high initial interest in science is not surprising.

> I have, for many years, wanted to pursue a career in science (engineering), so these stories did not really have an effect.
>
> I have a very clear and thought out career plan and it would take more than short stories to change that.
>
> I am already interested in a science career.
>
> My rating is not to say I have no interest, but my interest was already high and did not need to increase.

Other students specifically noted that they found the stories interesting, but did not increase their interest in science as a career.

> The stories were interesting, but it didn't influence me on what I'd like to go into.
>
> They were interesting, and easy points, but not really an effect on my interests.
>
> They were nice to read but it didn't make me any more interested in science.

A few students noted that the stories did not pertain to their specific interests or to their specific career interests.

> They were interesting, but they aren't about what I am interested in.
>
> The stories didn't pertain to the scientific career I am pursuing.

The stories were not about any scientific career I'm interested in.

Decreased interest in science careers

Only eight students claimed that the short stories decreased their interest in science as a career. Of those eight, only three left comments. The student comments are not surprising.

Made me hate science even more than I have this whole semester.

They were very boring

I changed majors.

While these students' views are extremely negative, they represent only a small fraction of the students in the course. We would have liked to follow-up with these students to gain greater insight as to the source of their frustrations, but the surveys were anonymous so follow-up was not possible.

Instructor views on use of historical short stories

The instructor of the introductory biology course studied, Glenn, is a professor in the Biology Department at the large Midwestern university where the study was conducted. Glenn was interviewed by the first author during the summer of 2008 - one semester after the short story implementation. The following discussion represents major themes drawn from the interview with Glenn concerning the use of the historical short stories in his course. While the interview often explored the nature of science more generally, this discussion will be limited to Glenn's view of the short stories and their use in his introductory biology course. We have organized the discussion by providing a summary of Glenn's ideas or thinking related to each theme or sub-theme followed by excerpts from interview transcripts to support our discussion. We have tried to provide larger portions of text rather than isolated phrases to provide greater context for Glenn's words. Also, whenever possible, we have provided text from multiple portions of the interview

as a form of triangulation of Glenn's thinking. Pseudonyms have replaced all names in the interview transcript and discussion.

Short stories as outsourcing

Glenn viewed the short stories as outsourcing opportunities in that he did not have the time/expertise to create them. Glenn was glad to have the short stories as a resource and noted that he would have never generated the materials on his own. His lack of expertise and time would have prevented him from creating the stories. While Glenn's expertise lies with biology content, he would have had to expend tremendous amounts of energy and time to develop historical stories. Furthermore, while he claims to have an intuitive understanding of the nature of science and that his understanding is growing, he admits that he is only comfortable engaging in conversations about deep philosophical issues to a certain extent. He was glad to have a resource to which his students could go for more "digestible" information.

> And to be honest, I don't have the expertise to be able to tell that story in any…it would take me a lot of effort to be able to tell those stories the way I tell stories about biology because there I do have the expertise. There I know that, and when a student asks me a question, I can usually give them some kind of reasonable answer. The short stories have been developed, researched by people, and the folks in history and so forth, who know far more about that aspect than I do. I don't want to have to go to the work of learning that, I'm quite happy to have you guys provide that to me. So,….and it is in this relatively encapsulated, digestible form that I can give to students outside of class. I don't have to burn class time to talk about Darwin's historical context or whatever. I think those are the things that I really…..that is why I choose to use those. (Glenn, 1:12:00)

> The second part is my level of knowledge and my level of understanding. What do I have a firm grasp on? I think we have talked a little about how I have learned some things along the way, not necessarily from the short stories, but from Todd and deciding that I need to think about this more deeply. Would I really be comfortable trying to explain to students if I decided to use the word methodological naturalism? Would I feel like I could really explain that well? Concisely? Accurately? I know what it means, it means that you can't say that God did it. ok, that is fine, but saying that to students is going to do nothing more than alienate them because many of them think that God did do it at some level. Even if it was that God set up evolution. So, could I really…do I have the

> knowledge base and comfort level to really explain a pretty difficult idea in the nature of science well enough and in a concise enough fashion. (Glenn, 1:20:00)
>
> Just a general comment is that I would have never generated [the stories] on my own, never. I would have been dead three hundred years before that got high enough on the priority list, so I am appreciative, in the sense, both that I wouldn't have had the time and I wouldn't have had the expertise to put them together. So I look at them now as quite useful resources that had been generated with virtually no effort on my part (Glenn, 2:04:15)

Glenn specifically used the outsourcing metaphor when noting that the short stories contained geological content that he did not want to take biology class time to address. Furthermore, he notes that he would not likely have the content expertise to discuss the age of the Earth concept in as great of detail as the stories did. Glenn's value of his instructional time will be a consistent theme throughout our discussion.

> One is, with the age of the earth short stories, you know, the estimates we have of the age of the earth are really important for a lot of things in biology, a lot of ideas in biology, but this isn't a geology class and I don't want to spend a lot of time doing that. So, I guess I kind of look at those two short stories as a way of out sourcing…getting my students some information about the age of the earth and why we think it is the age that we do and a little bit about the history and the people who were involved, without my spending very much time in class at all on it. In class, I talk about stratigraphy and radiometric dating, but really not much. So I really just kind of outsource those ideas to the short stories.
> (Glenn, 1:11)
>
> For those, I think that the content there that I don't want to teach but is useful for them to know about is that this isn't something that just came out of the blue, this is something that people have been talking about for a long time, people had these different ideas, you know, etc, etc. At one time it was 100,000 years old, and why that was wrong. I mean, these are geology topics and in fact those stories were developed for the geology class, but they have very strong connection to and implications for biology and when I'm talking about biological diversity, I'm frequently saying, "well, this group of organisms appears in the fossil record 420 million years ago". I mean I can just throw those numbers out, but what I'm trying to do is provide some context of understanding of where those numbers come from without sacrificing a lot of my time to teach geology, which I couldn't really teach anyway cause I don't really know geology. For me it is a stretch to just understand the principle of radiometric dating, let alone many other details that I'm sure elude my current understanding. (Glenn, 2:10:00)

Glenn also notes that having the stories come from an "outside" source is valuable. Rather than students thinking the stories are just one more thing the professor wants, he hopes the students read them as they would a textbook, and that a sense of authority be placed with the stories.

> I think that that is critical. I think that if it was coming from me, it would be just perceived as more of the same. The fact that it is coming from somebody else, who they don't know and who sounds important, I think is probably useful. In fact, at one point we were using versions of the short stories that would have been in the preliminary or pilot thing and it didn't say anything about who had authored it. And I specifically asked Todd to put that on there because I didn't want the students thinking that I had written it for them. I wanted them to look at it in the same way they might look at a text book or a paper that I had…. (Glenn, 1:16:30)

Short stories compliment content instruction

In addition to providing instruction of content he did not want to take class time to cover, Glenn noted that the short stories augmented and provided context for the biological content he teaches. While Glenn wants to spend his instructional time covering biological ideas, the stories provide insight as to how the ideas came about and paint a picture of the people behind the ideas. Furthermore, Glenn notes how the stories provide context for the ideas to which he refers.

> The other three short stories that I use, Mendel, Wallace and Darwin, those three individuals are just absolutely central to what we're doing in that course. One of the fundamental themes of that course is genetics and evolution and their connections. So I was using those [short stories] in my view to augment what I was doing in class as opposed to outsourcing and at the same time, bring in something that I wasn't going to do in class. Which was to talk about these people and their particular histories and backgrounds and so forth. From my perspective, that was really the advantage to using those. (Glenn, 3:00)

> Certainly I talk about Mendel and talk a little bit about who he was, but much less than what was in the story. I talk about Darwin, a little bit about who he was, but much less than what was in the story. And Wallace I probably don't talk about really other than just to mention during presentation in class. So I'm really sort of using the short stories to provide an opportunity for the students to have a bigger, broader, more well-developed picture of who these people were than I want to

> take the time to do in class. What I want to focus on in class is, you know, the ideas that these people had and why they were important for biology and how we use them, those sorts of things. That is how I want to spend my time, but I think it is really useful for the students to have an opportunity to learn more about these individuals as people. (Glenn, 5:40)

> I mean, these are geology topics and in fact those stories were developed for the geology class, but they have very strong connection to and implications for biology and when I'm talking about biological diversity, I'm frequently saying, "well, this group of organisms appears in the fossil record 420 million years ago". I mean I can just throw those numbers out, but what I'm trying to do is provide some context of understanding of where those numbers come from…(Glenn, 2:10:00)

Short stories teach NOS

Considering the short stories were designed for improving student understanding of the nature of science, we are not surprised that Glenn noted the utility of the stories in this regard. While Glenn, who is not familiar with the science education NOS literature, does not discuss specific NOS ideas, he does make clear that he believes the short stories improve student understanding of how science works. He notes that the stories help students realize that science is messy and more complex than many students imagine. Glenn notes that the stories are about real individuals doing real science and that the "lone genius" model for science doesn't hold up for how science ideas are developed or how they are accepted. Science ideas take an unpredictable path to acceptance and the stories make clear that the notion "A leads to B" just doesn't work.

> Well….I think that…These people are, you know, extraordinarily important people in the history and development of biology. There's no argument about that. So I think that just from a historical perspective it is worth it to know something about these people. But I also think that it is useful to get a glimpse of how science really works and how it proceeds and I think that maybe the, you know, the two examples that I'm glad are part of those stories are number one with the Darwin and Wallace thing. You had two people working unbeknownst to each other in terms of what they were doing and what they were thinking and at some point along the line it becomes clear that they were both thinking the same sorts of things. That happens in science a lot. You've got research group A over here working on something and research B working here on something and they may not realize that there is a big connection but they both happen to go to the

same meeting or one of them publishes a paper. So, I think that is an important thing. A second thing, with the Mendel story, the fact that his work was lost, buried, unappreciated for, I don't know, 30 or 40 years. I don't know if that would happen today because information is, you know, more readily accessible, but even so, you know, sometimes insights are not appreciated immediately and it takes some further work before that occurs. So I think that both of those are little insights into how science actually works from the perspective of the people who are actually doing science. So, I don't know for sure how much I …I know I talked about how Mendel's work was ignored, you know, it wasn't understood how important it was for a long time. So I think that is some important insight into the process of science. So, that is why I think it is important for them to know more about these people and learn from their stories. (Glenn, 7:00)

But one of the things that I value about the short stories in this context is I think it helps the students understand that the world is a hell of a lot more complex than they understand. It wasn't just Darwin, inspired by God or the Devil or whoever who came up with this ideas in a blinding flash of light, which is a very easy way to think about it. It was actually part of a whole bigger picture and there were a lot of people who had different pieces of it and who impacted Darwin in various ways. So, I think that what I'm trying to say is that it tries to pry the students away from that "the world is black and white" view and helps move them toward the world is gray view and it is not as simple as "A happened and that led to B". It is a complex interaction. And I think the stories capture some of that complexity. You know, I think the clearest example is Wallace and Darwin, but even the age of the earth stories. The interaction between the various people who were thinking about this and the church and public opinion and with…amongst the group of people who were thinking about the age of the earth, it is not a simple story. It is a complicated story. So in a lot of ways, a lot of the student comments could be summed up as, "wow, this was more complicated than I thought it was". I think that is a step forward. I mean, I think that seeing that the world is not a simple place, seeing that the world is complex is a useful step in terms of understanding the world as well as understanding science and how science works. So, to me, that seems like a useful thing…it is a reason that I want to use the short stories. (Glenn, 1:09:30)

I think it may help alleviate some of those things. I think this is one of Todd's main goals that demonstrating that science is a social activity that it involves other people that the lone genius working on a mountain top is a very inaccurate description of science and that is some of the things that I read when I read student responses. One of the things I notice is that students recognize that "oh gee, I thought science was working in a lab by yourself and it turns out science is interacting with all kinds of people". So, I think that they might attract some people who would otherwise be like, "oh biology, all your going to be is stuck by yourself working at a microscope". There are some people who do kind of like working on microscopes, but that is really not all that they do. (Glenn, 1:59:00)

Very little NOS instruction time

Using short stories outside of instructional time to illustrate and teach about NOS concepts is of great value to Glenn. While Glenn believes that understanding the NOS is important for his students, he allocates very little direct instructional time to these complex issues. He estimates only one-thirtieth of his time is spent on NOS issues, including time he uses in class to discuss the short stories.

> I spend some time at the beginning of the semester talking about theories and laws, and the like. Then I spend some time in the middle talking about methodological naturalism, although I don't use that phrase, and talking about discovery science vs experimental science. Those are probably only the sort of explicit….we are talking about only 20 – 25 minutes of explicit instruction on the NOS. But along the way in context I try to hit the more tentative NOS by saying "this is what we know now" things like that along the way. (Glenn, 57:00)

Yet, Glenn notes that the use of the short stories has increased the total amount of time he spends on the NOS in class. He also speculates on his colleagues' view of including the NOS. Not surprisingly, Glenn believes his colleagues would think anything that distracts from strict biology content instruction does not belong.

> Oh yeah. I don't think there is any question about that. It is still not huge, but I think the fact that I want the students to talk about….and we are taking some discussion time in class to talk about it. I guess I would look at it as it is all part of a system and the fact that we were doing the short stories and thinking about some NOS stuff made me want to take some time to talk about the theory things in more detail and methodological naturalism and discovery science vs experimental science in more detail…probably reminds me to keep reminding the students about the tentative nature of science. So, I think that it is no one thing in isolation, it is kind of all these things working together that have led to an increase in the amount of time and energy and effort that I am putting in to the students in terms of their understanding of the NOS. But it still is…. sum total is no more than a class period, so it is 1/30 of the time in my class. Do I think that is an appropriate amount of time? I don't know. I'm sure that I have colleagues who would think it was an inappropriate amount of time and that I was spending too much time on it. I guess I look at it and I think, this is probably the bare minimum amount of time that is going to be of any value. If I spend any less than this, I may as well not do it at all because it isn't going to mean anything. Could I spend more time on it? Well I'm not an expert in NOS, I'm sure I could spend

> more time on it, or I could have guest lecturer. But I'm not sure I want to sacrifice anymore of my content time. (Glenn, 1:15:00)

Not only do the short story discussions themselves increase the time, the purpose of the short stories has perhaps affected how Glenn constructs his lectures. From working with the short stories Glenn has begun to consider how he might provide more insight into the human side of science and strives to include some information about the people behind the ideas. Glenn does admit that advances in technology have made finding this information easier, but also notes that he may not have thought to include human aspects were it not for the short stories.

> hmmm… Well, in a sense, as funny as this might seem. I think there is an impact right there (Picture of carl woese). It is becoming increasingly common for me to include pictures and descriptions of people who were important in the development of a particular idea or in the discovery of whatever. It is a little bit conflated in the sense that partly that this is a result of its technologically easier to do that. I mean, I can get onto google and find a picture of carl Woese. Twenty years ago when I started teaching, you couldn't have done that. If the textbook I was using happened to have an overhead that had a picture of Carl Woese, or more likely Watson and Crick, I could do that. But today, I can do that for anybody basically who….I have a picture of Kenneth Miller in my presentation, the author of this book they are going to be reading. So the point is, that I think the short stories and the ideas, this humanizing science idea, which is kind of the goal or subtitle of Todd's project has sensitized me to the notion of why just say so and so did this, why not show a picture of them and tell a little bit about them. And let's see if we can't have the pictures we show not be all old white guys. I mean, can there be some women, some diversity. And of course in some ways that is a tough challenge because of course old white guys had more opportunities to make these kinds of contributions, but the point is that I think that has been a real change. It is connected to or conflated with the easy technological access too. But just the idea of doing it, I mean, just because it is easy to do technologically doesn't mean you are going to do it. If you don't have the idea that it might be useful for the students to see that this was a person, is a person, or whatever. That is at least one example. (Glenn, 1:25:00)

Content Focus

While Glenn notes that his colleagues would think that any NOS instruction would be too much, he admits that his chief concern is also the biology content. Glenn believes that

learning about the history and people behind the biology concepts is important, but struggles to rationalize giving up valuable instructional time to discuss these topics. Several times during the interview, Glenn notes that every second he spends on explicit NOS instruction, is a second less of content instruction – that "it is a zero sum game".

> I think that most intro bio teachers struggle from the perspective of "how do I fit all of this in?" "All this" being all this incredible amount of information which is what the field of biology currently includes. We know a lot of things and there is no way you can talk about all of it in any kind of sensible way in a semester long or year long introductory biology course. So you are going to have to be prioritizing and deciding what aspects am I going to leave out. And I think most of my colleagues would look at [the short stories] and say this is just one more thing that is going to make me leave out biology and why would I choose to do that. So I think that likely relatively few biology instructors would be interested in incorporating this into their class. I could be wrong about that, but that is my suspicion. (Glenn, 15:00)

> What I want to focus on in class is, you know, the ideas that these people had and why they were important for biology and how we use them, those sorts of things. That is how I want to spend my time, but I think it is really useful for the students to have an opportunity to learn more about these individuals as people. (Glenn, 5:40)

> I think there's two. I think I have probably mentioned both of them, but to mention them while your asking, I think the two are obviously, time, it is a zero sum game. Every second that I spend talking explicitly about the NOS is one less second that I spend talking about, sort of, you know, biological discipline ideas. So it becomes a triage or prioritization problem. (Glenn, 1:19:15)

Stories useful in context of content instruction

With Glenn's focus on content, we are not surprised that he would not want to devote a unit to the nature of science. Glenn notes that he wants the students to learn about the development of the ideas or the people behind the ideas while they are learning about the ideas themselves. Glenn also explains that he believes this contextual instruction would help students better understand NOS concepts.

> I would have never used it as a unit. If what you are telling me is the circumstances I was in was, ok, here is this block of short stories, we want you to

> spend a week or two weeks going over – I would have never done it. (Glenn, 11:00)
>
> Maybe I'm not understanding your question, at least I think I understand. The only way that I was interested in doing this was to interweave it into what I was already planning to do. Adding up front or in the middle somewhere, anywhere, you know, a unit that was specifically "ok we are going to spend the next several class periods talking about the nature of science"…I wouldn't have wanted to spend my time that way. I'm trying to think how I might defend that, you know, what is my rationale for that. I think what it boils down to is I want to have them look at NOS issues sort of in context as we are talking about those things in class in terms of….beginning of the semester we are talking about the history of life on the planet and the great age of the planet and, you know, when these kinds of organisms were around and so forth. To me, that is the kind of context in which I want the students to know how we come to this conclusion. When we get to the point we are talking about genetics ideas and Mendel and evolutionary ideas and Darwin, that is the point at which I want them to….So what I think it really boils down to is I want to….to me it seems best, and I don't know that I have evidence that would convince me or anyone else, but to me it seems a priori best to have the nature of science instruction in context with, you know, the biological concepts or ideas that it is related to. I think it is important that they learn about the NOS, but I guess my fear is that if they learn about the nature of science out of context, quote learn about it, if they are exposed to the nature of science out of context that they are not really going to learn it, that they are going to learn it better if it is in context. So that is my rationale, as poorly supported by evidence as it might be. (Glenn, 13:00)

Reduce student resistance to evolution

Throughout the interview Glenn repeatedly indicates that he believes NOS understanding reduces student resistance to biological evolution. This belief is not unfounded (Southerland and Sinatra, 2003) and is a major driving force for Glenn's inclusion of the short stories and explicit NOS instruction. Glenn especially notes the Darwin and Wallace stories as useful in battling student resistance to evolution. He notes that students are largely unaware of Wallace's work and that others, besides Darwin, had been working on the idea of evolution for quite some time. When asked about the short stories' impact on student content understanding, Glenn forcefully notes that all he really cares about is reducing student resistance to evolution. Most all of Glenn's decisions regarding NOS instruction are somehow linked to his concern with student resistance to

evolution including his explicit, in class discussions on the term theory and the concept of methodological naturalism.

> On the other hand, I think there has become, and it is the whole controversy over evolution that has become the flashpoint that is the lightening rod that is leading the charge on this. And I think it is becoming increasingly clear to a broader and broader range of scientists and college level and other level instructors that the public in general does not understand what science is and what it can do and what it cannot do, etc. So I think that maybe, I would still say it is probably a minority, but maybe there is a growing minority of science instructors that recognize that spending all of your time on disciplinary content is not going to get you where you want to go. Where you want to go is real understanding of at least some of that content. And I don't think you can get to real understanding of at least some of that content unless the students have a clearer idea of what science is and how it operates than they typically have. So, you are going to have to sacrifice in my estimation. Sure I could talk about more groups of invertebrate animals or spend time talking about, you know, whatever, but I have chosen to spend at least some time, both presenting perspectives on the NOS myself, having the students read the [short stories], having them do some discussions in class and so forth. So I'm taking some time to do this, but it is clearly a zero sum game. Whatever time I put into NOS is less time that I will put into biology content and I think a lot of people would be unwilling to give up any. (Glenn, 17:30)

> I don't think there is any question in my mind of which I found most useful and like the best – it was the Wallace story. It is the one that I really wanted when we talked about this to begin with. Why? Because evolution and Darwin are so closely tied together. This is an example of the appeal to authority thing, well you believe in Darwin and I believe in God and my authority can beat up your authority….you know what I mean. It really is that sort of simple. So I think that students have this notion that Darwin, all on his own without any input from anybody, which is hooey because there were people thinking about evolution well before Charles Darwin, they just didn't have a good mechanism and they didn't have enough evidence. Their notion is that he is this authority figure and he stood on the mountain top and bushes burned and he made pronouncements and whatever else needs to happen and therefore all biologists believe this. Well, that's not of course the way it works at all. Darwin's ideas have been modified, expanded, improved upon. It is not like whatever he said is what we still bow down to or anything like that and it is not like he was the only person thinking about it and that is why I think the Wallace story is so powerful, is to see that there was someone else who these students have no knowledge of and I'm sure 99% of them have never heard of Wallace. When they write about this, that is one of the things students comment on that they were surprised that there was somebody else doing this kind of thinking and so that is what I'm trying to get to so I find the Wallace story most helpful because I think it is the most surprising.

And it directly erodes away this "Darwin is the authority figure" notion and the story itself is so compelling. I mean this guy had some adventures. (Glenn, 30:00)

By the time we get to evolution, I have used the word theory in several scientific situations. So the red-flag component about theories goes down. (Glenn, 59:00)

Somehow I feel [teaching NOS] decreases the…..resistance to being there, somehow it lowers the level of students being upset, getting up and walking out and confronting me publicly. (Glenn, 1:04:42)

But one of the things that I value about the short stories in this context is I think it helps the students understand that the world is a hell of a lot more complex than they understand. It wasn't just Darwin, inspired by God or the Devil or whoever who came up with this ideas in a blinding flash of light, which is a very easy way to think about it. It was actually part of a whole bigger picture and there were a lot of people who had different pieces of it and who impacted Darwin in various ways. So, I think that what I'm trying to say is that it tries to pry the students away from that "the world is black and white" view and helps move them toward the world is gray view and it is not as simple as "A happened and that led to B". It is a complex interaction. And I think the stories capture some of that complexity. You know, I think the clearest example is Wallace and Darwin, but even the age of the earth stories. The interaction between the various people who were thinking about this and the church and public opinion and with…amongst the group of people who were thinking about the age of the earth, it is not a simple story. It is a complicated story. So in a lot of ways, a lot of the student comments could be summed up as, "wow, this was more complicated than I thought it was". I think that is a step forward. I mean, I think that seeing that the world is not a simple place, seeing that the world is complex is a useful step in terms of understanding the world as well as understanding science and how science works. So, to me, that seems like a useful thing…it is a reason that I want to use the short stories. (Glenn, 1:09:30)

I don't think we ever want to treat the NOS just before evolution, then is seems like evolution is special or different that you have to make excuses for or something. I wanted some time to deal with NOS before we got to evolution. (Glenn, 1:38:00)

I guess what I am saying is, if [the short stories] had zero impact on their understanding of content, I would still assign them the short stories because of the other reasons I have for assigning the short stories. Does it help them understand the content? I don't know and I'm trying to imagine in the context of evolution, that is, the Darwin and the Wallace stories…. I would be happy with lowering their resistance [to evolution]. (Glenn, 2:07:00)

> My expectations is that maybe it reduces their resistance to learning about evolution a little bit, maybe it gives them a little bit broader understanding of the history of our understanding of the age of the earth, but beyond that I don't care. (Glenn, 2:11:00)

High level of short story implementation

From our past work studying short story implementation, we know that Glenn's level of implementation, while perhaps not as extensive as possible, was extremely high. Glenn had his students complete five short stories and the embedded questions, held small group discussion based on the short stories, had students reflect in writing on their discussions and took time in addition to short story discussions to address NOS concepts. Of course, we were curious as to why Glenn choose to implement the stories so significantly. Glenn's explanation essentially notes that since he believes the stories are worth while, he needs to send that message to his students and encourage them to engage meaningfully with the stories if the students were to receive any benefit.

> Well, I guess it is a trivial reason. I wanted you and Todd to be able to have these things tested at some high level rather than a cast off. But I think the real reason is, what would the value be of just having them read it? Zero. Most of them wouldn't read it or wouldn't read it carefully. So, I guess, from my perspective, what it boils down to is how could you have implemented this at any lower level and had the students get anything out of it? Unless there is some kind of expectation that they are going to be held accountable for this, they are just not going to do it. And I don't mean to say that makes them bad people, that is just human nature. So, my job as I see it is to set up an environment where it is to their advantage in some way to actually read it. And I suppose the advantage is not to look bad with their partner when they discuss. Also, there is some contribution to their grade, although they weren't assessed in any way…whatever they wrote they got points for. So , I guess from my perspective, this is about the minimum that could be done and had any expectation that this would be beneficial for the students. If you didn't have them write about it, if you didn't have them discuss it, they just weren't going to do it, they weren't going to read it. And even if they did read it, they wouldn't get as much out of it as if they had actually taken the time to actually write something about it and then discuss some of their writing with a colleague. So, I guess my basic take was, look if I'm going to do this at all, I want the students to benefit from it. This is the thing that is going to help them benefit from it. (Glenn, 1:29:00)

Future use of short stories

Importantly, Glenn intends to continue using all five short stories in his course even though the research project has ended. His intent to continue using the short stories strengthens our interpretation that Glenn saw great value in the short stories and that he believes the stories will help him promote the goals he has for his students.

> I'm in the process of working on 211 for this fall and I'm still planning to use all 5 of those stories even though you guys aren't planning on collecting data as far as I know. So, I found it valuable enough to continue it, I guess. (Glenn, 4:00)

> It is already on my syllabus, they are written in as, I'm calling them assignments basically. I'm going to do for sure those five. It is actually going to be substantial chunk of their grade this year. Let me give you a quick idea. This isn't set in stone, but…..it looks like it will be close to about 10% of their grade. It'll just be that they did it, that is basically all it will be. I'll have to look at it again, but some part of the points were for their typed answers and some part for their in class discussion reflection. (1:32:00)

Summary

Our results indicate that the use of historical short stories in post-secondary science courses has reportedly positive impact on student interest in science careers and students claim to have gained interest and knowledge in the NOS. Additionally, the course instructor sites several benefits for inclusion of the historical short stories and intends to continue using the shorts stories in their course. Most forcefully, the instructor notes perceived decrease in student resistance to the idea of biological evolution when including the short stories and the NOS into their curriculum.

Implications

While post-secondary instructors might realize the importance of nature of science understanding, few are willing to sacrifice "content" instruction to address these difficult concepts. Also, instructors are not likely familiar with the science education literature on NOS instruction and the need for explicit/reflective NOS instruction (Abd-El-Khalick & Lederman, 2000). Importantly, historically accurate short stories may be a way to begin integrating NOS into post-secondary science courses. As is demonstrated by this study, the rich context and content of the stories have perceived value for post-secondary

instructors whose main concern is delivery of content. Furthermore, the increased student interest in science as a career will likely be looked highly upon by post-secondary science instructors who often view their role as training future scientists. While we do not claim that historical short stories are the "magic bullet" to solve the perceived crisis in the science pipeline, the current study provides some evidence that developing a more humanistic view of science through historical short stories may help maintain the interest of those students who show initial curiosity in science as a career.

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