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ABSTRACT

This paper examines how conceptions regarding the legitimate purposes and day-to-day course of science influence students' evaluations of science in the popular media. The students involved in this project attend a secondary all-girls school. Their concept of science focused on practical, life-enhancing goals pursued through the complex, time-consuming process of modeling nature. Students used this conception to critically evaluate popular accounts of science. Science and scientists congruent with this image were more admired and trusted than activities and individuals that were not. Their critical ability is thus limited by the limitations of their model of science. Teaching the process and dynamics of scientific activity may help students critically evaluate science. A Web-based curriculum was used to provide students with notetaking capabilities and concept mapping functions. (Contains 12 references.) (Author/YDS)

Using models of science to critically evaluate scientific arguments: A look at students, science education, and the popular media

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Abstract

I examine how conceptions regarding the legitimate purposes and day-to-day course of science influence students' evaluations of science in the popular media. The students involved in this project attend a secondary all-girls school. Their concept of science focused on practical, life-enhancing goals pursued through the complex, time-consuming process of modeling nature. They used this conception to critically evaluate popular accounts of science; science and scientists congruent with this image were more admired and trusted than activities and individuals that were not. Their critical ability is thus limited by the limitations of their model of science. Teaching the process and dynamics of scientific activity may help students critically evaluate science.

The importance of students' conceptions regarding the nature of science has been well documented (Carey & Smith, 1993; Songer & Linn, 1991; Edmondson & Novak, 1993). I will examine one relationship between students' conceptions and their reasoning—that between the ideas held by girls at Central School for Girls (CSG) regarding the purposes of science and their ability to critically evaluate scientific claims in the popular media.

What is the point of science?

My investigations began with a survey instrument completed anonymously by 32 secondary school girls at CSG. The survey included: (a) Likert-scale items addressing the frequency with which students use science for particular purposes and their perceptions regarding how one *could* use science, and (b) open-ended questions eliciting student depictions of science, scientists and scientific activities. I will use the survey data to describe the girls' perspective, and then relate their depiction of science to their responses in a critical thinking curriculum, conducted with a larger group that overlaps the survey group.

Likert-scale items probed what students see as the uses of science (Table 1). I presented a number of specific and general uses for them to consider, inquiring how frequently they use science for these purposes, and whether they thought science *could* be useful in that way, even if they did not use it themselves.

Table 1. Frequency of use and perceived utility.

	Use once a month or more	Could use (may not use personally)
Staying safe & healthy	58%	78%
Solving everyday problems	50%	78%
Understanding other people	42%	50%
Taking a stand on political issues	22%	31%
Test experts' credibility	23%	N/A

Each cell represents a separate question; marginals do not sum to 100%

Of these presented uses, the girls found the strongest link to be between science and "staying safe and healthy;" over half stated that they used science for this purpose at least once a month, and 78% agreed that science could be useful for this purpose. Solving everyday problems was the second most popular purpose. As we move to less traditional pedagogical notions of science, students see less connection to science. Fewer reported using science to "understand people," and only 50% thought this was even potentially useful. Additional drops occurred in the realm of politics or critically evaluating experts. From this, I characterize students' perspective as relating science to traditional pedagogy and practical or humanitarian concerns.

When presented with specific reasons for wanting to learn more about science, students again showed a interest in practical and caretaking functions (Table 2), though enjoyment of science was their number one reason. Personal medical decisions, employability, and sharing science with their children in the future clustered near the top; relating science to other areas of knowledge provided less motivation.

Table 2. Reasons for continuing to take science courses in the future

	% of students agreeing
Enjoy learning about science	66%
Making decisions about personal health	59%
Want a job that uses science	55%
Teach own children about science	50%
Want to be a scientist	43%
Improve thinking about non-science topics	41%
Stay current with political issues	41%
Students responded to all questions, so percentages do not sum to 100%	

These patterns were echoed in the girls' responses to open-ended questions, especially their interest in life-enhancing uses of science coming through more strongly. In addition, an interest in science as driven by discovery and experimentation surfaces.

When asked "What is the most interesting thing scientists do?" students pointed to experimentation, discovery and improving life (responses categorized in Table 3):

> *"Find cures for diseases and other things which can help improve the well being of people/environment."*

> *"The most interesting thing that scientists do is that they publish and teach the information they have learned"*

> *"Discover stuff, form new substances, discover new species of animals."*

Table 3. Students' perceptions of the most interesting aspects of scientific work; categorization of open-ended responses.

	% of students mentioning
Discovery & experimentation	65%
Improve life	35%
No other reason was mentioned.	

According to students, the least interesting parts of a scientists' job are calculations and tedium (responses categorized in Table 4):

> *"I think calculating numbers and diagrams lack interest. I detest watching science movies that use diagrams that are not life like or easy to comprehend. It just makes a hard subject harder"*

> *"Write up reports to what they are doing + what advances + other things have happened."*

Table 4. Students' perceptions of the least interesting aspects of scientific work; categorization of open-ended responses.

	% of students mentioning
Calculations	38%
Boring tasks & memorization	28%
Dissemination & teaching	10%
No other reason mentioned more than twice.	

Finally, girls tended to choose scientific roles models who work on behalf of humankind and the environment:

> *"I would want to be like Lauren Hutton. She, in addition to being a model, is a dedicated volunteer in Africa. She works along side other scientists to promote prevention and awareness."*

"I would want to work with animals and their environment."

"I don't know exactly who. I would want to go to underdeveloped countries and give medical attention to all the people. I don't want to stay in the U.S. and just be a surgeon."

"I would want to know a lot on many topics, so I could help many people"

Categorizing their responses (Table 5), 65% are role models in "helping" professions (medical, environmental and teaching). Even generalists were motivated by humanitarian interests, as illustrated by the last quote above.

Table 5. Role models chosen by students

	% of responses
Medical	35%
Environmentalist	15%
Teacher	15%
Engineer	12%
Generalist	12%
No other response mentioned more than twice.	

In summary, the girls are concerned with improving the quality of life for people and other living creatures, and they believe that scientists are--or should be--motivated by these concerns as well. Furthermore, the day-to-day activities of science are seen as experiment leading to discovery, but only through time-consuming, tedious procedures and calculations. This pattern is consistent with that found among British undergraduates by Ryder, Leach & Driver (1999).

This view of science provides a standard by which students judge scientific claims and activities. Those that fit this image of science are judged reliable, while violations create suspicion. Thus, students ability to critically evaluate science depends heavily on the completeness and accuracy of their model.

Relating the purpose of science to critical thinking about science

In addition to providing us with insight into the girls' images of science, the survey influenced our decision to construct a critical thinking module structured around science on the Web. The girls reported considerable exposure to science in the media. Seventy-six percent encountered information in the media that related to their science classes at least once a week; 75% used material from their science classes in informal discussions at least once a month.

While the girls learned most about science from textbooks, between 60 to 70% also reported learning from television, the Internet, magazines and movies (Table 6). Over the course of their lives, they may well learn more about science from popular sources than formal education. Among popular sources, the Web is growing in importance: "computers are now almost as common as a cable television subscription, and Internet subscriptions are nearly as prevalent as newspaper ones." (Stanger & Gridina, 1999, p. 5).

Table 6. Amount learned from sources of scientific information.

	Learn nothing, or almost nothing	Learn a few things	Learn many things
Textbooks	3%	9%	88%
Other books	19%	63%	19%
Television	22%	56%	22%
Internet	31%	50%	19%
Magazines	31%	59%	9%
Movies	38%	56%	6%
Video games	97%	3%	0%

Factors mediating the girls' relationship to the scientific community were also motivating. The most common reasons for feeling isolated from the scientific community (Table 7) or being turned off science (Table 8) related to personal failure or lack of comprehension:

Table 7. What makes students feel isolated from the scientific community?

	% of students mentioning
Failure and lack of comprehension	52%
Never felt isolated	30%
Boring tasks	6%
No other reason mentioned more than once.	

"In Biology, when I truly did not understand what was going on in class. I felt like everyone else understood-so I felt obligated to go along w/ the 'flow.'"

"I guess I've always felt turned off by science until this year. It was never one experience, it was just the idea in my head that I wasn't brainy enough to be good at science so why try."

"In seventh and sixth grade I had this teacher that wasn't supportive. It made it so boring and it was really hard. High school was so much easier than 7th and 6th grade."

Table 8. What turned students off of science?

	% of students mentioning
Failure and lack of comprehension	42%
Poor teaching	32%
Boring tasks	19%
Unpleasant, "gross" tasks	6%
No other reason mentioned more than once.	

In contrast, the girls are inspired by enjoyable classroom experiences, active participation, and scientific activities that go beyond the classroom (Tables 9 and 10).

Table 9. Experiences that make students most want to learn about science.

	% of students mentioning
Enjoyable class experiences	35%
Conducting experiments in class	17%
Participating in the science fair & informal science	24%
Real-world medical & life-improving experiences	21%
Nothing makes them want to learn about science	10%
Students may have mentioned more than one reason. No other reason mentioned more than once.	

"When I got stitches in first grade + when I broke my arm in second grade, I loved learning about what was in a bone from books + my parents. I was also obsessed with being an astronaut, I checked out books that were way too difficult for me, I was 5-11 yrs. old."

"I really wanted to learn more in biology this year. I wanted to really play an active role in cleaning our planet. Help inform people about the greenhouse effect etc...."

"Was when I was in fifth grade and we had to collect all different kinds of leaves and classify them. I felt involved also what we did this campy thing and identified all the different plans you could eat in the woods"

Table 10. Experiences that make students feel part of the scientific community.

	% of students mentioning
Participating in the science fair & informal science	46%
Successful experiences with science	14%
Real-world applications of science	11%
Coursework in science	11%
Conducting experiments in class	11%
Never felt part of the scientific community	29%
Students may have mentioned more than one reason. No other reason mentioned.	

We needed to encourage active participation in real-world encounters with science; more and more, this will include the Internet. However, the Web exposes students to information that ranges widely in its reliability. To guard effectively against misinformation and fraud, have positive experiences with science, and use scientific information effectively, students need to critically evaluate arguments on the Web.

With this in mind, we designed a critical thinking curriculum using the Web-based Integrated Science Environment (WISE; Linn, Bell & Hsi, 1999). The module consisted of an introductory section that presented criteria for critical evaluation, and an evaluation section. The WISE framework allowed students to visit third-party Web sites while providing scaffolding in the form of parallel text, note-taking capabilities and concept mapping functions. Eighty-one girls, grades 9, 10 and 12, participated in the curriculum as part of their regular science coursework. This group included the ninth- and tenth- graders who participated in the survey above. A complete description of the project and findings is provided in Brem, Russell, & Weems (in preparation).

I will focus primarily on the girls' strategies in assessing source credibility, a common issue in critical thinking curricula and standards (Harris, 1997; Halpern, 1996; Kirk, 2000). Initially, the process seems relatively straightforward. To determine whether a source is knowledgeable and trustworthy, we examine their credentials and experience, and scrutinize the situation for evidence of ulterior motive or conflict of interest.

However, for students with little knowledge of academia and the scientific community, this is far from easy. They must sort out which institutions are reliable places for a particular sort of science. They must decide what qualifies as relevant credentials; the role of a biochemist in cloning research may not be as obvious as the part played by an orthopedic surgeon in prosthetic research. Finally, students need to understand what motivates scientists and the publishers of popular accounts of science.

Assessing credibility was a challenge for many students. In some cases, it was their own knowledge that was lacking:

> *The article said that Lovell-Badge is a doctor at the University of Pavia in Italy. [...] You may not know if this university actually exists or not.*

> *We are not sure whether to believe this story or not, because we have never heard of something like this before, but it could be possible!*

They relied on the appearance of credibility when they could not establish the relevance or importance of information, assuming that affiliations were relevant and reputable:

> *The authors seem more reliable because there are more of them, and they are all at universities, or schools.*

Often, too, the problem was exacerbated by incomplete accounts:

> *What kind of credentials does Dr. Laidler have to be exploring this area? Why doesn't it tell who the author is of the article? [...] The article doesn't tell who Dr. Laidler is and what he already know about the evidence.*

Because of these limitations, the girls often relied upon their prior conceptions of what "real" scientists and science are. Their model bears a strong similarity to the one that emerged from the survey. Credible scientists are:

- Unprejudiced and interested only in advancing science
- Engaged in activities with a clear purpose, often humanitarian in nature
- Carrying out complex, time-consuming procedures, often involving animal models

According to the student model, "real" scientists do not possess ulterior motives. One of the most frequently detected motives was financial gain, one that is relevant to almost all areas of human endeavor. For example, one site referred to the money that could be made selling clones with the body of a horse, and a human face (although a hoax, many students evaluated it as a sincere site):

> *The doctor gains the recognition of the public. As well he is out to make a lot of dinero. One of the first things the author talked about was how much money he would be selling the horses for. [...] He is in it for the cash and fame.*

However, ulterior motives are defined in a way that suggests an incomplete understanding of what drives scientists. Very few groups recognized that legitimate scientists can be motivated by career goals or prestige:

> *...most scientists want their theories to be published in a journal, and will staunchly fight against any research that goes against their original theory. So, why wouldn't they do*

everything possible to make their research seem ABSOLUTELY TRUE?

Moreover, "real" scientists are expected to improve life, helping human beings, other creatures, or the environment:

> *The doctor who says he makes these horses is "obsessed with monsters" and was not making them for scientific reasons. He was planning on selling them for $40,000 each. [...] It lowers the credibility because a real scientist wouldn't be cloning for money they would be doing to advance science research.*

> *In the article, the author seemed to explain that the only thing gained by this project is money. They'll be sold as pets for $40,000. Yet it never really stated if this new "animal" could help the scientists learn more about cloning organs, etc. that would be put in good use to humans. [...] Lowers Credibility because they seem to be only interested in the money aspect*

In contrast, a site discussing the use of monkey parenting as a model for human child abuse was more favorably received:

> *it can help mothers and children get along and not live in an abuseful relationship. [...] they aren't doing it to help themselves, they are doing it to help others. they aren't making any money out of it and have nothing to gain other than knowing that families will get along.*

Students defined scientists not only by their goals, but by the everyday work they do. Activities consistent with the students' notion of the day-to-day activities of science made for a more favorable evaluation, while activities that violate this process generated suspicion. For example, the scientific process is time-consuming, in part because the course of events cannot be predicted or controlled completely. At the cloning site, many students were skeptical because they did not think that cloning could become an assembly line process:

> *"Our specific detail on credibility was that it never said or gave support that the Dr. who is the spokesman was from a true lab or not. Also it never said how long it took to make the first clone, but they will be making about 50 in the next year to be sold."*

> *"Lowers because something like this has never been accomplished nor is it possible with our technology and knowledge today. 50 clones is a lot of clones in one year for something so newly developed."*

At a second site, students were favorably impressed because the scientists had used mice in their work on the genetic influences on sex trait expression. Although the area of research was not familiar, using mice was:

> *"The article said that Lovell-Badge is a doctor at the University of Pavia in Italy. The doctor and some of his researchers conducted several experiments on transgenic mice to determine how DAX1 and Sry work. I believe that could be true because scientists do a lot of experiments on mice to determine what might happen to the human body."*

At the horse clone site, the girls were dissatisfied because the scientists apparently started with horses, bypassing the usual lower animal models:

> *"I have never heard of any animal being mixed with another animal. While there have been several breakthroughs with growing extra limbs on flies and mice, there was quite a fuss over it, and that seems to be the extent of our mutating abilities. [...] The fact that no such thing was ever done first on mice or flies, as most tests are, makes it much less reasonable."*

Concluding thoughts and recommendations

Should students rely on their models of science to critically analyze popular accounts? That depends upon the accuracy and depth of the models. Believing that scientists have no motive beyond helping and discovery may lead to an unwarranted level of trust. Conversely, if students believe that purpose is central to science, and do not recognize the purpose of a study, they may dismiss it prematurely. For example, if you do not know that a mouse makes a good model for human respiration, then spending millions of dollars treating mouse asthma will not seem like "real" science. And if you do not know much about the pharmaceutical industry, you may not recognize the pressures that affect experimentation and disclosure.

Part of building students' critical thinking skills lies in teaching them the skills of analysis. But they must also develop a model of the nature of science, and the ability to recognize the gaps in that model. Others have raised the concern that students are not being taught the nature of science (AAAS, 1997); strengthening their critical thinking skills is yet another reason for doing so.

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