Transforming History into Science Inquiry

by Douglas Allchin

Abstract. I present an adaptable lesson format for integrating history of science and inquiry learning. Its features include: (1) motivating students by connecting science to its cultural and human contexts; (2) nurturing scientific ways of thinking through a historical case; (3) sustaining student engagement through storytelling; (4) inspiring students through the value of scientific discovery and potential role models; and (5) understanding the nature of science through authentic, fully contextualized examples.

Darwin, Mendel, Watson and Crick: their familiar histories are frequently shared in the biology classroom. But what about Archibald Garrod, André Jagendorf, or Joseph Goldberger? How can historical perspectives contribute to science teaching? What opportunities lie beyond the periodic anecdote or vignette as diversion? Here, I describe a standard format for how history can inform and enrich almost any biology lesson.

A recent review of articles in *American Biology Teacher* across six decades documented widely shared views on the value of using history in biology teaching (Allchin, this issue; see also Allchin, 2013, pp. 28-39; McComas, 2020). Five major reasons for adopting historical perspectives were commonly cited:

(1) *motivating students*, by connecting science to its cultural and human contexts;
(2) *modeling and nurturing scientific ways of thinking*;
(3) *sustaining student engagement* through human stories and/or narrative formats;
(4) *inspiring students* by dramatizing the value of scientific discoveries — and of the scientists behind them as potential role models; and
(5) *understanding the nature of science* in its multiple dimensions.

But *how are these abstract virtues of using history realized in concrete classroom lessons?* In this paper, I describe how a teacher can integrate these multiple goals seamlessly in an interactive case study format. It may serve as a prospective (yet adaptable) template or scaffold for enhancing biology education using history.

There are, of course, many ways one might venture into history: textbook sidebars, television documentaries, biographies, performing dramatizations, reading original papers, replicating classic experiments, and more (e.g., McComas, 2020, p. 533). However, models of instruction now routinely underscore the importance of inquiry learning. Namely, engage students in exploratory self-directed investigation or problem-solving. This now popular approach poses a problem for history. Namely, inquiry is open-ended. History is not. The past is past. It cannot be changed. It especially cannot be changed if the goal is to preserve its latent lessons about the nature of science. Most approaches to history of science involve studying it objectively, at arm's length, remotely. This is the particular problem I address here. *How does a science teacher transform history into an inquiry format?* I will use a recent lesson in *ABT*, "The Vaccine Skeptics of 1721" (Allchin, 2022), as an illustration (for accompanying visuals, see also http://shipseducation.net/smallpox).

The first (and perhaps most challenging) task for any teacher is motivating students. Many types of "hooks" are possible. The historical approach invites us to consider the original impetus behind any scientific concept. What cultural events motivated the research? Why did a particular scientist become involved in the topic? These contexts help show relevance and human interest, which students can readily share. Significantly, this motivates not only the target concept, but also the process of science that led to it.

Consider, for example, developing a timely lesson on the efficacy and safety of vaccines. Rather than race to current controversies — unresolved in public discourse — a reflective educator may ask, "When did this understanding arise historically?" Someone could easily return to the case of Edward Jenner and cowpox — the very origin of the term 'vaccine'. Or tap into Louis Pasteur's famous inoculation of a nine-year-old boy who had been bitten by a rabid dog. Or Jonas Salk and testing the polio vaccine. On this occasion, given the prominence of current anti-vaxxers, a case that highlights the issue of skepticism seemed optimal. So an apt choice of focus would be Lady Mary Wortley Montagu's work on smallpox variolation in the early 1700s. Many historical sources are available online. The work is greatly facilitated, however, by finding a fuller, more detailed, book-length account, such as Donald Hoplins' *The Greatest Killer: Smallpox in History*. Well-informed history is essential. If one plans to portray the nature of science accurately, one must avoid melodramatic or romanticized "myth-conceptions" (Allchin, 2013, pp. 46-76).

To open a case, set the scene vividly. Describe the cultural context, as well as the more specific biographical context of the central character. Here, this means dramatizing the emotional scourge of smallpox in the early 1700s and Lady Mary's own encounter with the disease. A smallpox epidemic—one of many—swept through England in 1713. One in five infected patients died. Note: while such a statistic is alarming, it is mindfully included to impress students and garner their attention. In this case, the central character also had multiple experiences that helped motivate her involvement (and with hers, ours). First, she lost a brother to smallpox in 1713. Second, two years later she herself contracted the disease and, while she survived, her skin became blemished with pockmark scars. She wore a mask in public to hide her face. (Here, one might amplify the drama by adding another dimension of cultural context: the role of a woman's beauty as part of her standing in elite society at that time.) This is all how smallpox *matters*, and how one engages students in the scientific story.

These contexts should arouse interest. But the science, central to the whole lesson, has yet to be introduced. How did the context lead to and focus attention on a specific scientific problem? This is the unknown that will motivate inquiry, thread through the ensuing narrative, and help structure the case as a whole. Here, a further element of context helps explain how Lady Mary was drawn into the science. In 1717 she and her son accompanied her husband on his ambassadorship to the Ottoman Empire in Constantinople. There, she visits the local Turkish baths and, given her background, Lady Mary is amazed at the beauty and unblemished complexion of the women there. How can that be? How can they all have escaped the ravages of smallpox?! She learns that they rely on a medical practice called *variolation*. It is largely unknown in Europe. She describes it in a letter to a friend. On this occasion, we have her original account, which provides an added sense of authenticity and involvement.

But the problem is not yet fully framed. To this scenario, we add Lady Mary's desire to protect her own son from smallpox. Namely, *should she have her son variolated?* One can easily elaborate the relevant questions. Is this procedure safe? What are the risks? Is it effective? To what degree? Here, then, we arrive at the central theme: assessing the credibility of scientific claims, specifically about the safety and efficacy of smallpox variolation. That scientific problem will carry the students through the entire case, although it has yet to unfold fully.

All that, just for an introduction? Well, yes. That's how important pedagogical attention to context and motivation is. If the aim is to engage students in their own learning, one needs to invest sufficiently in the set-up, orientation, and motivation. Cultural context, biographical context, and scientific context all set the scene and motivate inquiry into the target problem in a historical mode.

Nurturing Scientific Thinking | The Historical Scenario

One can, of course, just present the solution to students. That would follow the conventional teaching pattern of focusing on the conceptual content. One might even be tempted to catapult ahead in history and explain the physiology of the immune response and the role of vaccines in inducing the process—just how does variolation *work*? This is the alluring rhetoric of science-as-answers.

However, we should remember the importance of student inquiry. Ideally, students become active in their own learning. More important, perhaps, we want students to develop skills in thinking scientifically on their own. Accordingly, the educational focus shifts from the *products* of science to the *process* of science. From ready-made science to science-in-the-making (elaborated nicely by Flower, 1995). Namely, how do scientists collect evidence and reason?

So, the next step is to invite the students into the case, to explore the problem (Figure 1, position 1a). The student assumes the role of the historical biologist, *doing* biology. Scientific inquiry is set in a real scenario from history. You are now Lady Mary in 1717: "*How do you address the problem of the credibility of claims about variolation?*" In our case, students can easily imagine relevant questions to consider. What counts as evidence of effectiveness? Is historical experience sufficient, or does one need new experiments? Can one trust the medical practices of what seems to be a less advanced culture? From Lady Mary's Christian perspective, should one trust the testimony or actions of another religion? Will the Turks be honest about the risks? The engrafting is done by older women, not physicians. Who is an expert, here? How does one measure expertise? The history provides the essential details for reasoning concretely: about evidence, expertise, credibility, and trust. Students exercise their reasoning skills. They observe how others reason, too. Then they can explain their personal decisions, given Lady Mary's position.

At this point, in mid-inquiry, with its inherent unknowns and uncertainties, one may affirm all student efforts as legitimate. Where possible, students who have echoed actual historical figures can be noted, as further validation. Yet the students themselves do not have the tools available to resolve the many alternatives. Thus, the teacher returns to the actual history, here (Figure 1, position 1b). What did Lady Mary herself do? This provides a measure for the students to assess their own ideas (free from the psychological overtones of evaluation). Lady Mary is indeed impressed by the plain evidence of the low incidence of smallpox among the Turks. She decides to have her son variolated. But it is done by a doctor, Charles Maitland, who accompanied them to Turkey. Students may be invited to reflect on her decision, and to wonder whether emotion or cultural bias played a role.

Engaging Students with Narrative | The History as Roadmap to Inquiry

There is more to the science, of course. But without some structure or guidance, student inquiry becomes aimless. It has nowhere to go. Here, history provides another valuable element: a storyline. Through a historical narrative, one can thread together a series of inquiry episodes into a more complete learning sequence. The historical “hook” segues into a historical “line” — a storyline — that sustains student motivation.

From an inquiry perspective, history provides a *lineage of questions* (Farber, 2003). Each offers another opportunity for students to learn scientific practices. At the same time, from a classroom perspective, the history provides an engaging story. Stories are a major part of our lives, at least outside school. Here, the narrative format provides familiar human perspectives that allow students to sustain their interest and maintain the scientific focus. One should not disregard, then, the many *personal* struggles and conflicts involved in getting the science done. These add spice to the story, enhancing what students remember.

In the smallpox case, we follow Lady Mary as she returns to England several years later. There, she shares her experience and urges others in her elite circle to protect their children. When threatened by another epidemic in 1721, she decides to variolate her daughter, now four years old. Here, the narrative shifts focus to the doctor. Maitland is now reluctant to perform the procedure again, fearful for his reputation in London. While the premier scientific organization in England, the Royal Society, has received reports about variolation from trusted correspondents, it has not been widely endorsed. *What should Maitland do* (Figure 1, position 2a)*?* He has seen variolation work himself, but in his professional context, what evidence is appropriate? Here is another occasion for students to participate vicariously in the history. More discussion about evidence and credibility.

Eventually, Maitland enlists three members of the Royal College of Physicians to witness the event. And the variolation proves safe again. The story continues to unfold, drawing the students onwards. One of the witnesses is persuaded, and soon has his own children inoculated. Other of Lady Mary’s acquaintances agree also, especially among those who have lost relatives or friends to smallpox.

The case writer/teacher chooses the moments to delve into inquiry. As a result, time can be greatly condensed. Students can do a lot of science in a short amount of class time. The narrative connects the inquiry episodes. So, the story continues, helping to frame the next problem. Lady Mary continues her advocacy. She encourages another member of her social circle, Caroline, the princess of Wales, to variolate her children. But now the question involves the royal family and potential heirs to the throne! And the king, at least, is skeptical. Once again, students have the opportunity to flex their scientific thinking skills. There is more evidence now, especially among English patients. But with the political context, the stakes are also much higher! *What should the royal family do* (Figure 1, position 3a)*?*

After student discussion, the teacher reveals that, ultimately, the king instructs his physicians to conduct a formal experiment (Figure 1, position 3b). (But imagine the ethics involved?) Six inmates at the notorious Newgate Prison, already sentenced to be executed, are offered full pardons if they "volunteer" to be tested. Caroline wants to extend the test to children also, so a handful of local orphans are inoculated, as well. All the tests succeed. The king allows the daughters to be variolated, but *not* the sons, who are in the direct line of succession. Here, the teacher may want to allow the students themselves to design such experiments, or to discuss the historic ones, and to consider how best to manage the ethics involved.

Still, controversy continues. And so the narrative and inquiry for students also continues. Maitland now publishes on his advocacy. Critics respond. They disparage variolation as "a method practiced only by a few *Ignorant Women*, amongst an illiterate and unthinking People." They refer to "one of the most Learned and Polite Nations in the World" succumbing to "slender Experience," thereby discounting the Turkish experience entirely (quotes from Hopkins, 2002, p. 47). Debates in science are common. How are they resolved? Why is consensus important? Students may now adopt a new position as a member of the Royal College of Physicians: *What evidence, based on whose testimony, would be sufficient to endorse widespread (possibly mandatory) public variolation? What policy would you support?* (Figure 1, position 4a)

I have described this series of episodes in some detail, to illustrate how the historical narrative can provide coherence and unity to a string of successive inquiry activities (Figure 1). In this case, they are all unified by a common theme: credibility, expertise, and the sufficiency of evidence. This case was originally developed for middle school students (Remillard-Hagen, 2012), but of course the historical-inquiry method applies to any level, with teachers developing a level of problem-solving challenge commensurate with their own particular students.

Case writers should note one particular feature of the historical narrative, of special importance to inquiry. Even though the events happened three hundred years ago, they are presented in ongoing present tense. This is integral to the students participating in science-in-the-making, and not in a position to judge events of the past. The students proceed, as did their historical counterparts, blind to the outcome. That ensures that they reason *from* the available evidence *to* a justified conclusion. No staking of claims intuitively, then cherry-picking evidence and spinning arguments to match. This is a challenge for all inquiry learning, but far more precarious when the history is already done. Namely, no spoilers allowed! This is essential if students are to learn how science truly works.

Celebrating Science & Scientists | Historical Role Models

The story closes when scientists reach a solution or, in this case, an actionable consensus. By 1730, fewer than 900 individuals in England have been inoculated. Smallpox reappears in 1731, 1734, and 1736. But it is not until after an especially virulent epidemic in 1752—with over 10,000 deaths—that the Royal College of Physicians, two years later, endorses variolation. But the practice is still not widely adopted. At the end of the century, Edward Jenner introduces vaccination, which poses fewer risks, and it becomes common practice. The scientific resolution is also the end of the story (a "sinker" that brings an aesthetically satisfying sense of closure).

With the story concluded, it is time to take stock. The discovery of smallpox variolation is, in retrospect now, a prime occasion to celebrate the achievements of science. Here, that involves a medical procedure that dramatically lowered widespread death from smallpox. It is also an occasion to celebrate the work of the scientists: the anonymous healers in Turkey (who relied on sources even earlier in China and Africa), Charles Maitland, the King's physician who led the Newgate Prison experiment (Hans Sloane), and, of course, Lady Mary Wortley Montagu. The focus on Lady Mary is a special occasion for noting (with today's disparity in the science workforce) the participation of women in science. Indeed, this was a major reason for choosing her story over other possible historical cases relevant to vaccination.

Here, authentic history helps portray real people, not the romanticized heroes of legends. One need not idolize scientists as superhuman. Indeed, when one couples a scientist's achievements with their flaws and imperfections, students find "real models," not unrealistic "role models" (Allchin, 2020a).

One is free, of course, to explore the meaning of the case for today. As an epilog, one might ask: *What have we learned that might inform our acceptance of vaccinations today, for measles, for covid, or for other diseases, such as malaria, tetanus, typhoid, or the flu?* In this way, a historical case can be brought up to date, certainly not to be dismissed as mere "history," and therefore irrelevant.

Understanding the Nature of Science | History as Exemplar

While the story is finished, the lessons for science from the historical case are, ironically, not yet complete. The history has more to offer: namely, understanding regarding the nature of science — perhaps the main reason biology teachers turn to history. It is not difficult for students to discuss, "*What did you learn about the nature of science from this case?*" Each student inquiry question was also an excursion into some aspect of the scientific enterprise. Students naturally included these elements in their discussion. (Hence, it is important for the teacher or case writer to consider carefully how they problematize these nature of science dimensions. This helps dictate when, precisely, they insert inquiry questions, and how they frame them.)

In this case, the central theme is (obviously) credibility, with its interplay of personal trust, evidence, and expertise. But issues of gender bias and cultural bias also loom large. One might also discuss social class distinctions, professional hierarchies, and research ethics (with the element of power lurking throughout). These all add cultural and human significance to science, in what may at first have seemed like "just a story." After general class discussion, students are generally adept at writing an open-ended short essay describing what they learned about the nature of science (when prompted on each topic) and they can provide concrete examples from the historical case. After experiencing a few cases in class, they are often also ready to spontaneously find thematic connections between different cases.

The Historical Science Inquiry Model, Summarized

I have described at length the case of "Lady Mary Wortley Montagu & Smallpox Inoculation" (or "The Vaccine Skeptics of 1721") primarily to illustrate a general model, or template, for how to transform history into active inquiry. The elements are summarized in Figure 2, showing how the various benefits from using history correspond to features of the case structure. (For more details on case construction, see also Allchin, 2012, 2020b.)

First, history provides cultural and human context, as an opening to motivate inquiry and to frame the central question. Next, history provides a concrete scenario for students to learn scientific reasoning and problem-solving. Third, history also provides a narrative structure for linking together a series of separate inquiry discussions, while engaging students in the human dimension of science. Fourth, the resolution of the history is also an occasion for celebrating scientific achievements and seeing scientists as realistic role models. Together, these elements form the “hook, line, and sinker” that help to initially pique student interest, and then sustain it through a thematically unified and coherent narrative arc (Allchin, 2015). Finally, with explicit reflection on judiciously selected moments of inquiry, history is a source of lessons about the nature of science. Thus, this model addresses both (1) major curriculum goals — especially those about scientific practices and nature of science that are conventionally challenging to meet; and (2) the motivational dynamics of the classroom so essential to realizing those curriculum goals effectively. History is a valuable resource throughout, in multiple ways.

This case study structure contrasts with the various piecemeal approaches to using history found elsewhere (e.g., McComas, 2020, p. 533). Most importantly, it embraces the ideal of inquiry. Other models of synthesizing history and inquiry have been presented earlier in this journal (e.g., Crenshaw, 1979; Howe, 2009). This model endeavors to be more complete — specifically, to integrate all those features that seem most consistently important to teachers in their use of history. For more examples, and for resources that generally follow this model as a guide, one may examine the cases in *Doing Biology* (Hagen, et al., 1996; online at http://doingbiology.net) and on the *SHiPS Resource Center* website (http://shipseducation.net/modules). This issue also features another historical inquiry case that exemplifies this model: “The Railroad Workers’ Disease” (Azevedo & Sel Corso, 20XX).

The intent throughout is to teach biology, including scientific practices and the nature science. As shown here, historical perspectives can be (unexpectedly?) a fruitful resource. Ironically, then, we might teach *biology* more effectively by using *history*.

References

Allchin, D. (2013). *Teaching the Nature of Science: Perspectives & Resources*. St. Paul: SHiPS Press.

Allchin, D. (2015). Hooks, lines, and sinkers. *American Biology Teacher,* 77, 718-720.

Allchin, D. (2017). Historical inquiry cases for nature of science learning. *Cadernos da História da Ciencia* 13(2). http://ojs.butantan.gov.br/index.php/chcib/article/ view/276/263

Allchin, D. (2020a). Role models and real people. *American Biology Teacher,* 82, 365-365.

Allchin, D. (2020b). Using historical inquiry cases to learn nature of science skills. In W.F. McComas (Ed.), *The Nature of Science in Science Education: Rationales and Strategies* (rev. ed.). Dordrecht: Springer, pp. 595-607.

Allchin, D. (2022). The vaccine skeptics of 1721. *American Biology Teacher,* 84, 53-54. See also http://shipseducation.net/smallpox.

Allchin, D. (this issue).Engaging the history of biology: Why teachers care and how one succeeds. *American Biology Teacher*.

Azevedo, N. H., & Del Corso, T. M. (20XX). The railroad workers’ disease: A historical inquiry case of a remarkable triple discovery. *American Biology Teacher*, XX, XXX-XXX.

Crenshaw, N. (1979). Teaching the history of science through inquiry. *American Biology Teacher,* 41, 564-565.

Hagen, J., Allchin, D. & Singer, F. (1996). *Doing Biology*. Glenview, IL: Harper-Collins. http://doingbiology.net
Hopkins, D.R. (2002). *The Greatest Killer: Smallpox in History*. University of Chicago Press.
Howe, E.M. (2009). Henry David Thoreau, forest succession & the nature of science: a method for curriculum development. *American Biology Teacher*, 71, 397-404.
McComas, W.F. (2020). A typology of approaches for the use of history of science in science instruction. In McComas, W.F. (Ed.) (2020). *Nature of Science in Science Instruction: Rationales & Strategies*. Cham, Switzerland: Springer, pp. 527-550.
National Research Council. (2012). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas.* Committee on a Conceptual Framework for New K-12 Science Education Standards. Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.
Remillard-Hagen, E. (2012). Lady Mary Wortley Montagu and smallpox inoculation in 18th-century England. St. Paul, MN: SHiPS Resource Center. http://shipseducation.net/modules/biol/smallpox.htm.

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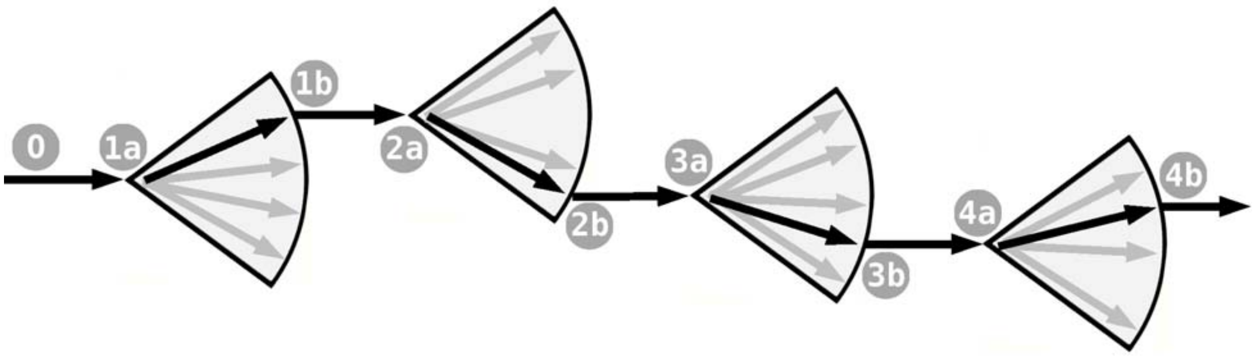
Figure 1. The lineage of inquiry questions, divergence of student responses, and continuation of the case history narrative for “The Vaccine Skeptics of 1721.”



(0) 1713. Smallpox in Europe, variolation in Turkey.

(1a) 1717. *Should Lady Mary variolate her son?*
What claims are credible? What is the evidence? Who is an expert?
(1b) ▶ She does — but it is done by a Western physician.

(2a) 1721. *Should Maitland variolate Lady Mary’s daughter?*
What claims are credible? What is the evidence? Who is an expert?
(2b) ▶ He does — but with witnesses.

(3a) 1721. *Should the royal family variolate their children?*
What claims are credible? What is the evidence? Who is an expert?
(3b) ▶ First, further experiments are done. Then: daughters, yes; sons, no.

(4a) 1723. *Should the Royal College of Physicians endorse variolation?*
What claims are credible? What is the evidence? Who is an expert?
(4b) ▶ Yes — but only in 1754, after a severe epidemic.

Figure 2. How the benefits of using history correspond to the structure of an inquiry case history, in the current model.