Abraham Trembley & the Creature that Defies Classification

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TEACHING NOTES

Summary

This lesson follows the 18th century investigations of hydra (*H. viridissima*) by Dutch naturalist Abraham Trembley. Students are invited to participate in the research, working virtually alongside Trembley, who ultimately received the Royal Society's presitigious Copley Medal for his discoveries. Students engage in many fully contextualized scientific practices and discuss reflecive questions that help highlight the nature of science. Here, the dilemma of classifying zoophytes serves as an occasion to invigorate the often dry topic of taxonomy, by focusing on the distinction between plants and animals—not nearly so simple as it may seem to the novice.

Major NOS features include:

- the role of interpreting observations
- the role of theory in interpreting evidence
- the role of experiments
- the role of unexpected results
- response to criticism
- the material culture of science
- ethics in scientific conduct
- the role of gender and access to science

THINK Activities

The primary purpose of these questions is for students to develop scientific thinking skills and to reflect explicitly on the nature of science. The questions are open ended, and the notes here are only guides about the possible diversity of responses. In many cases, there is actual history as a benchmark (which can be shared after the students' own work), but by no means does the history indicate an exclusively "correct" answer. Accordingly, avoid overt clues or "fishing" for answers, implying that a particular response is expected or considered "more right." The case study should be illustrating the blind process of science-in-the-making. To help promote thinking skills, the teacher should encourage (and reward) thoughtful responses, well articulated reasoning, and respectful dialogue among students with different ideas or perspectives.

Where the case study here echoes NOS features students have encountered in other case studies, the relationships should be noted and perhaps contribute to deeper discussion. This form of repetition and integration with prior knowledge significantly deepens the NOS lessons.

[Think 1] Based on these observations, what would justify the choice in favor of one classification or the other? Which traits seem most important and "carry more weight"?

We expect the students to perceive that in Trembley's perspective there is equivalent amount of arguments in favor of animal or plant nature of the polyp. In this case, any decision must consider factors other than the number of evidences. Here we have a place for students to discuss the role of personal decisions in science-making and how such decisions are taken. It is expected for them to discuss such aspect of nature of science while they themselves must make a decision.

[Think 2] How should the results of the cutting experiment help in making a decision on classification?

While addressing this question, the students explore the balance (or imbalance) between the scientist's personal ideas and the evidence obtained by experiments. To achieve an answer, they must think about how much evidence must exist or how strong an evidence must be for a scientist to get rid of a previous conception or not.

[Think 3] What should you conclude in the face of this new result? How should this new evidence about mode of reproduction be interpreted with respect to the criteria of voluntary movement and locomotion used earlier?

One may use this question to evaluate consistency between the previous response and this one. The students are experiencing the process lived by Trembley: it is one thing to make predictions about a test constituted in light of potentially reinforcing one's own ideas – remember that Trembley thought he really would kill the organism with the cutting process – and it is another thing to make an intellectual decision after seeing something unexpected to happen. Should the scientist develop another test or should him/her give his previous ideas up after one experiment that could prove him/her wrong? This is the dilemma faced by the students after these three Think questions.

[Think 4] Facing this dilemma again, is it necessary to conduct more experiments and make more observations,or should you reassess the criteria used to classify organisms as either animals or plants?

Differently of the previous couple of questions, this one does not ask about considerations regarding on a scientist's personal ideas, but the ideas shared by the community of scientists – such as criteria for classifications. What happens when these criteria do not suffice anymore? Is this an example that could lead to what the philosopher of science Thomas Kuhn called a scientific revolution? How long should a scientist insist on a current paradigm? These are questions that lye on the process of developing a response for this Think exercise, and, as educators, we expect to assess how our students perceive the role of persistence, personal motivations, theory-laden thinking and paradigm-shifts in science.

[Think 5] Recalling that you are handling small aquatic creatures, why do you think they did not survive the trip? What procedures and care do you think are needed to ensure the survival of these organisms during a several-day trip by horse or carriage from The Hague to Paris?

This is an epistemic problem, i. e., students need to create an hypothesis and find a way for testing it. While doing so, they must consider both animal and plant necessities, since it is still not clear what this creature is. Should they prime for common necessities between these two realms of life? Or should they try to guess, once again, whether those creatures are animals or plants before taking a decision? While reflecting on these details, it is also expected that students reflect on what is behind the processes of coming up with a hypothesis and a test.

[Think 6] Once again, how should we interpret the unexpected outcome? How does this new observation help characterize how you classify the creature? Again, should you change your position on the animal/plant distinction? Explain.

Once again, we need the students to reflect on the nature of experiment and on the meaningfulness of a result to the process of taking decisions in science. Along this historical narrative, this may be the aspect of nature of science more frequently addressed by the students. Thus, an instructor may take this chance for assessing consistency in the students' thinking process and/or how deep students discuss this point. A question the instructor might try to answer is "Can my students get deeper and deeper in the discussion on the nature of decisions in science? Or would they stick with their original perspective?" If your students indeed stick with their first perspective on the animal/plant nature of the polyps, you can provoke them to think about why they are insisting in their first idea, regardless the evidence against it.

[Think 7] What are some possible reasons for skepticism (like Reaumur's) about generation by budding in polyps? As Trembley, how would you try to persuade him about the reliability of the new observations?

Here, the students must address the nature of criticism and skepticism in science. It is a question for them to think about the role of these features in the process of making science within a community of researchers, what may also lead them to think about science as a collective enterprise. If students chose to think in a more epistemic way, they are expected to address the question of science-making being theory-laden, i.e., posing questions, developing tests, and interpreting results are steps of scientific process that can be better understood under the light of a scientist's ideas and under the current theories and paradigms. If a single group of students is able to address both dimensions of nature of science – science as human, collective enterprise and science as a theory-laden process –, we can tell that those students are starting to perceive and understand the concept of whole science.

[Think 8] Do you think that just the action of trapping a supposed prey is sufficient to classify an organism as an animal? If so, how should we deal with apparently carnivorous plants (such as the Venus fly trap, sundews, or pitcher plants)?What further information, if any, would help resolve this dilemma?

This question reflects the matter of establishing criteria and acceptable exceptions for those criteria in science, notably in biological sciences. While considering Trembley's case about feeding in polyps and the fact that he is using this case to reaffirm his animal-nature idea, once more the students must address science as being a theory-laden construct, and reflect about the role of a scientist's point-of-view when he/she is developing his/her studies. Also, when the students are asked about if they could think about further studies, we expect them to address the role of chemical nutrition in feeding, anticipating the next step of the story and feeling in Trembley's shoes.

[Think 9] How would you characterize the contributions of this knowledge to his research?

With this question, we intend to see how students address confirmations and denials of hypotheses in science and, through their responses, to check once again how well they understand the epistemic nature of science.

[Think 10] Why, even after several public presentations witnessed by many credible people, might some people reject the complete regenerative ability of polyps? How might you respond to such skeptics?

This is another question for students to reflect about the role of skepticism and criticism in science; however, this time, students must also consider a new dimension of nature of science: the one regarding communication of performed works and trust about the communicated data. It is not expected for students to achieve a "right answer", but to consider a whole range of possibilities behind distrust in science, such as personal beliefs, previous personal work that made one famous, the role of nationalism in accepting or not someone's research, among other factors.

[Think 11] Is this fair? Is this plagiarism? Given his social status as a "mere" tutor, what can Trembley do? Was Trembley's "strategy of generosity" a mistake? What might be the consequences for Baker?

In this question, we expect students not just to point to plagiarism as a wrong, but also to imagine a solution to it— assuming the role of a representative of the Royal Society, for instance. For them to be able to do so, they must reflect on the implications of plagiarism in science and on how ethics assumes an important role in nature of science, too.

Note: Henry Baker received the Copley Medal himself the following year (1744) for work on crystallization. He would later endow an eponymous lecture series at the Royal Soceity that continues to this day.

[**Think 12**] Recall Charlotte Sophie, the mother of Trembley's tutees. How do you think she might have contributed to the investigations if she had been invited to participate?

The primary purpose of this reflection is to highlight how science in the 18th century largely followed the gendered nature of European culture at the time, which peripheralized women in politics and scholarly activites. For example, one might discuss Carl von Linné's gendered views of reproduction in classifying plants or in the naming of mammals. One may equally want to mention women who *did* find distinction in science in the period: for example, Émilie du Châtelet, renowned for translating Newton's *Principia*. Later in the century, Caroline Herschel (younger sister to William Herschel) distinguished herself in astronomy. Marie-Anne Paulze worked largely in the shadow of her husband, Antoine Lavoisier. Sophie Germain and Marie Agnesi made significant contributions to mathematics.

One may partly compare their status to the challenges that Trembley faced as not being a member of the wealthy elite. At that time, at least, scientific authority seems to have been acknowledged largely within the boundaries of power and privilege in society.

[**Think 13**] **NOS Reflection Questions**

These reflective function partly for recall and review but also to help consolidate and thus complete the central NOS lessons of the case study. They are essential to "closing" the lessons and making the NOS thinking explicit and articulate.

What does the case of "Abraham Trembley and the Creature that Defies Classification" reveal about the following aspects of the nature of science?:

- the role of interpreting observations [Think 1, 3, 9]
- the role of theory in interpreting evidence [Think 4, 6, 9]
- the role of experiments [Think 2, 4, 7, 8, inversion experiment]
- the role of unexpected results [Think 3, 4, 6, 8]
- response to criticism [Think 7, 10, witnessing of experiments, sharing of samples]
- the material culture of science [Think 5]
- ethics in scientific conduct [Think 11]
- the role of gender and access to science [Think 12]

Summary of Inquiry Questions, NOS themes and Corresponding Benchmarks in the NGSS

	Narrative & Inquiry Question	**Nature of Science**	**NGSS Scientific Practices**
1	Trembley finds an unfamiliar organism (a hydra) in a local pond. ⊡ *Given that the creature exhibits traits of both plants and animals, how should you classify them?*	• role of interpreting observations	● SEP 2 - Modeling: "Evaluate merits and limitations of two different models."
2	Trembley contemplates cutting off a "branch" of a polyp, to see if it will regrow, as plants do. ⊡ *How will the results of such a test help his interpretation?*	• role of experiments	● SEP 7 - Engaging in argument from evidence: "Determine additional information required to resolve contradictions."
3	He cuts the polyp fully in two and unexpectedly *each half* grows into a new individual! ⊡ *How do these results change your view of the criteria used earlier?*	• role of interpreting observations • role of unexpected results	● SEP 2 - "Construct and/or support an argument with evidence, data, and/or a model." ● NOS: "Scientific findings are frequently revised and/or reinterpreted based on new evidence."
4	⊡ *Facing the plant/animal dilemma again, what is your revised view, or is it necessary to make more observations or conduct more experiments?*	• role of experiments • role of unexpected results • role of theory in interpreting evidence	● SEP 2 - Modeling - "Evaluate merits and limitations of two different models...in order to select or revise a model that best fits the evidence." ● SEP 1 - Asking questions: "Ask questions that arise from ... unexpected results, to clarify and/or seek additional information."
5	Trembley consults a fellow naturalist, who requests a sample of polyps to replicate the experiments for himself. But the organisms die en route. ⊡ *What is your next step?*	• material culture of science	
6	Trembley observes that the polyps can grow new branches which detach and become independent individuals. ⊡ *How do you now classify the creature? Again, should you change your concepts of animals and plants? Explain.*	• role of unexpected results	● SEP 2 - Modeling - "Evaluate merits and limitations of two different models...in order to select or revise a model that best fits the evidence." ● NOS: "Scientific findings are frequently revised and/or reinterpreted based on new evidence."

	Narrative & Inquiry Question	Nature of Science	NGSS Scientific Practices
7	Trembley's colleague doubts the new findings, adamant that animals reproduce only by mating and eggs. ▶ *What are some possible reasons for skepticism about generation by budding in polyps? How would you try to persuade your critic about the reliability of your observations?*	• role of theory in interpreting evidence • response to criticism	● NOS: "Scientists' backgrounds [and] theoretical commitments ... influence the nature of their findings." ● SEP 7 - Engaging in argument from evidence: "Determine additional information required to resolve contradictions."
8	Trembley then observes the polyp engulf and digest a worm.. ▶ *Do you think that the action of consuming prey is sufficient to classify an organism as an animal? What further information, if any, would help resolve this dilemma?*	• role of experiments • role of unexpected results	● SEP 2 - Modeling - "Evaluate merits and limitations of two different models...in order to select or revise a model that best fits the evidence." ● NOS: "Scientific findings are frequently revised and/or reinterpreted based on new evidence."
9	Trembley uses a popular theory of animal nourishment to design more tests, but they yield no new insights. ▶ *How would you characterize the contributions of this knowledge to his research?*	• role of interpreting observations • role of theory in interpreting evidence	● SEP 2 - Modeling: "Identify limitations of models." ● NOS – "Scientists and engineers rely on human qualities, such as persistence, ...imagination, and creativity."
10	Trembley shares his results, but some continue to doubt his conclusions. ▶ *Why, even after several public presentations witnessed by many credible people, might some people reject the complete regenerative ability of polyps? How might you respond to such skeptics?*	• response to criticism	● SEP 7 –Engaging in argument from evidence: "Respectfully provide and receive critiques about a proposed procedure, explanation, or model, by citing relevant evidence and posing specific questions." ● NOS – "Scientific knowledge has a history that includes refinement of, and changes to, theories, ideas, and beliefs over time."
11	An ambitious naturalist in England reads Trembley's correspondence and publishes it as his own work. ▶ *Is this fair? Is this plagiarism? Given his social status as a "mere" tutor, what can Trembley do? Was Trembley's generosity a mistake?*	• scientific misconduct	● NOS – Science is a human endeaavor: "Scientific inquiry is characterized by a common set of values that include...honest and ethical reporting of findings."
12	The mother of Trembley's tutees was estranged from the family, but renowned across Europe. ▶ *How do you think she might have contributed to the investigations if she had been invited to participate?*	• role of gender and access to science	● NOS – Science is a human endeavor. "Men and women from different social, cultural and ethnic backgrounds work as scientists."