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Enhancing Argumentative Skills in Environmental Science Education

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Dealing with complex problems often requires advanced argumentative skills. We sketch how to reconstruct and evaluate arguments and outline how fostering argumentative skills is implemented in the Environmental Sciences curriculum at the Department of Environmental Systems Sciences (D-USYS) of ETH Zurich.

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Enhancing argumentative skills is one of the crucial elements of the *Critical Thinking Initiative* at ETH Zurich. The objective of this initiative is to complement students' knowledge and methodological competences in their respective discipline. Curricular measures have been put in place to promote students' skills in thinking creatively, critically and independently. They also enable them to acquire experience in addressing interdisciplinary and system-oriented problems, such as problems of sustainable development in intercultural teams.[1] The mission of ETH's Department of Environmental Systems Sciences (D-USYS) clearly complies with this initiative.[2] Within the department, the Transdisciplinarity Lab USYS TdLab[3] is explicitly dedicated to developing and facilitating teaching and research that focuses on complex problems at the interface between academia and society and in interactions with interest groups.

Dealing with complex problems often requires argumentative skills that go beyond the natural abilities even of gifted students and lecturers. Analyzing arguments and concepts is the standard philosophical method, also termed "critical thinking" (Bowell and Kemp 2015). In this paper, we sketch how to reconstruct and evaluate arguments (cf. Brun and Hirsch Hadorn 2014) and provide a checklist (Box 1). Furthermore, we specify several courses that foster argumentative skills (Box 2, p. 208).

Reconstructing Arguments

Arguments come up if it is unclear or controversial whether or why a statement or claim is true, e. g., "It is very likely that in the future, heat waves will occur more often and last longer than today." The purpose of arguing is to come to a reasonable agreement on whether a claim can be held, starting from shared claims and showing that the controversial claim is supported by, or even deducible from, these shared claims. The supported claim is the conclusion, the supporting claims are the premises. Take another simple example: "If rain forest has to be cleared for the production of some biofuel, then this biofuel has a poor environmental performance. Biofuel B is cultivated on rain forest land in Indonesia. Hence, B has a poor environmental performance." In practice, arguments are rarely presented in such explicit form. Often, some premises are left implicit, and formulations are incomplete or mingled with irrelevant information. Therefore, before arguments can be evaluated, they need to be reconstructed: one has to leave out what does not contribute to the argument, replace imprecise or incomplete formulations, add implicit premises and arrange the elements of the argument in order to render its structure conspicuous.

Evaluating whether Arguments Are Correct

To evaluate an argument, we need to ask: Are the premises true? Is the argument

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1 *www.ethz.ch/en/the-eth-zurich/education/policy.html*
2 See *www.usys.ethz.ch/about/index_EN*.
3 *www.tdlab.usys.ethz.ch/about.html*

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logically correct? The first question calls for expertise about the subject matter at issue; the second is addressed by argumentation theory.

What "logically correct" means depends on the type of argument. Deductive arguments are logically correct if they are valid. An argument is valid if the truth of its premises guarantees the truth of its conclusion. Proofing whether an argument is valid requires formal methods, but we can informally assess the validity of a deductive argument by asking whether it is possible for its premises to be true while its conclusion is false. If this is possible, then the argument is incorrect and hence a fallacy. For example:[4] "If a model correctly captures the causal processes of the target system, then it fits the observational data. Model M fits the observational data. Hence, M correctly captures the causal processes." This is a fallacy (called "affirming the consequent") because the model may not correctly capture the causal processes even if it fits the data, for instance if its misrepresentations cancel each other out.

Many arguments found in the sciences and in public debates are non-deductive arguments. Such arguments are correct if their premises provide a good reason for accepting their conclusion. In contrast to deductive arguments, they are risky. Consider this inductive argument: "95 percent of examined people infected with *Plasmodium vivax* suffer from malaria. Jones became infected with *Plasmodium vivax*. So probably, Jones will suffer from malaria." Its premises may give a good reason to accept its conclusion, but the conclusion can be false even if the premises are true (Jones might belong to the happy five percent). Further important types of non-deductive arguments are causal arguments and arguments by analogy. In a causal argument, we conclude that a factor F is causally relevant for an event E from the premises that two situations are relevantly similar and that E occurs only in the situation in which F is present. In an argument by analogy, we conclude that certain objects have a feature F from the premise that they possess relevant similarities with other objects that have F. Causal arguments are familiar from interpretations of experimental results. Arguments by analogy are in play when scientists draw conclusions from the behavior of experimental systems to the behavior of some target system.

Evaluating the correctness of a non-deductive argument can be tricky. One reason is that additional premises can weaken such an argument. If we learn that Jones has a genetic modification that immunizes against malaria in 95 percent of all cases, then the premises of the above argument will no longer support the original conclusion, but rather its negation. Thus, a non-deductive argument is correct only if all the relevant information has been taken into account. Whether this is indeed the case is often difficult to decide. More specific fallacies include: inductive arguments based on a non-representative sample (such as a sample whose members have features that do not match those of the population); arguments by analogy based on an irrelevant analogy (i. e., an analogy that does not increase the probability of the inferred feature); and causal arguments in which a causal relation is inferred from a mere positive correlation. For instance, A and B may be positively correlated by accident (increase in birth rate and number of storks), or because they are effects of a common cause (barometer reading and upcoming storm are both effects of decrease in atmospheric pressure). Another causal fallacy >

BOX 1: Checklist for Analyzing Arguments

Identify arguments – are they:
- *deductive arguments* or *non-deductive arguments* (e. g., inductive arguments, arguments by analogy, causal arguments)?
- *complete* (all relevant premises and conclusion are mentioned)?

Check whether relevant concepts are:
- *ambiguous* (i. e., have two or more different meanings)
- *vague* (i. e., not precise enough, thus making it unclear whether a specific case falls under it or not)
- *too general*

Clarify concepts by:
- mentioning an *example*
- explicitly *differentiating it* from other concepts
- referring to an *acknowledged source* (e. g., encyclopedia entry)
- giving a *definition*

Evaluate arguments – are they:
- *valid* (for deductive arguments: must the conclusion be true if the premises are true)?
- *correct* (for non-deductive arguments: do the premises strongly support the conclusion)?
- *sound* (i. e., correct/valid arguments with true premises)?
- *formally fallacious:* e. g.,
  - by *denying the antecedent*?
  - by *affirming the consequent*?
- *otherwise fallacious:* e. g.,
  - due to the *neglect of relevant information*?
  - due to an *unrepresentative sample*?
  - due to *irrelevant* or *weak analogies*?
  - due to their drawing causal conclusions from *mere positive correlations*?

Evaluate arguments' contribution to a discussion:
- Is a complex argumentation consisting of several single arguments *consistent*?
- Are the arguments *problem-oriented* regarding:
  - the *burden of proof* (i. e., is the own position being defended without the burden of proof being shifted to the opponent)?
  - *relevance* (i. e., do they support the claim at issue rather than a weaker one or do they attack the claim of the opponent rather than a stronger one)?
- Do they respect the opponent's *freedom of speech* (e. g., do they attack the opponent's claim rather than the opponent)?
- Do they adequately deal with *implicit and shared premises*?

4 An extensive list of fallacies can be found at *www.fallacyfiles.org*.

is the inference from "A is causally relevant for B" to "B is not causally relevant for A", as in: "Global warming is causally relevant for an increase in CO_2 and not the reverse, for CO_2 always increased with a delay after the rise in temperature." This argument disregards the feedback between the two factors.

Evaluating what Arguments Contribute to a Controversy

Evaluating whether an argument is correct is not enough. One also needs to consider how different arguments interact. Furthermore, even a correct argument with true premises may fail to secure reasonable agreement on a controversial claim. In evaluating an argument, we also need to assess what contribution it makes to the debate. To do this, we need to ask questions such as the following:

First, are the controversial claims supported by arguments? Fallacies in this area include evading the burden of proof by treating one's own claims as self-evident, or shifting the burden of proof by demanding a justification of the opponent's position instead of defending one's own. Consider the following exchange: A: "Nuclear phase-out isn't possible on the basis of renewable energies alone." B: "That's wrong, it's possible on this basis alone." A: "Well, you first have to prove that." In this case, both opponents need to argue for their respective claim. Hence, A should not simply shift the burden of proof to B.

Second, are the arguments relevant for the debate? Do positive arguments really support the claim that needs to be supported (and not a weaker claim)? Do negative arguments really attack the opponent's claim (and not a stronger claim)? A notorious fallacy (called "straw man") consists in targeting a claim that is easier to attack than the opponent's, as in: "It makes no sense to speak of anthropogenic climate change, because it's natural that the climate changes; it always has." This misses the point, since the phenomenon to be explained is the increase in global mean temperature by at least 0.64 °C within 50 years, not any kind of climate change. Recognizing such fallacies requires clarification of the concepts involved. In this case, the concept of climate change needs specifying.

Third, are the premises treated adequately? That is, are the opponents aware of which implicit premises they are committed to? Do they respect shared premises? Do they treat as shared premises claims that have not been justified, but from which the truth or falsity of the claim at issue directly follows (fallacy of *petitio principii*)?

Finally, do the arguments respect the opponent's freedom to justify or criticize claims? One fallacy here would be to attack the opponent personally, for instance by claiming that she/he is either ill-informed or biased, because personal interests are involved (argument *ad hominem*).

Implementing Argumentative Skills into Science Education

Developing argumentative skills requires three things: learning some argumentation theory that provides a method for analyzing arguments and arguing correctly; conscious practice, which translates the theoretical knowledge into actual ability; and adopting a reflective and open-minded attitude, which makes the practice effective and sustainable (Lau 2011). Box 2 lists some courses devoted to this threefold task for different audiences.[5] The courses profit from involving lecturers from philosophy and the sciences as well as students from different disciplines.

BOX 2: Implementing Argumentative Skills into Science Education at ETH Zurich

Courses that foster argumentative skills (course numbers in parentheses):

- In *Analysing Texts* (701-0707-00L), students learn how to grasp, summarize, analyze and evaluate the content and line of argumentation of texts.
- *Argumentation and Science Communication* (860-0017-00L) contains a module in which students at the Institute of Science, Technology and Policy (ISTP) are introduced to argument evaluation, with a focus on assessing computer simulations for policy advice.
- *Critical Thinking im Unterricht: Argumente erkennen und beurteilen* is a course for lecturers at ETH or University of Zurich[a] which conveys methodological foundations for promoting Critical Thinking in higher education. From 2016 onwards, this course will be offered in German (fall term) and English (spring term).

Courses that focus on the application of argumentative skills to specific subject matters *(students' comments in italics)*:

- In *Philosophy of Science/Exercises* (701-0701-00L/701-0701-01L), students learn to engage with problems in philosophy of science and thereby to apply and refine their skills in critical thinking about science and the use of science.
  "For me, the course has been very instructive and interesting. It introduced me to a completely different way of thinking and discussing fundamental aspects of scientific research."
- In *Philosophical Issues in Understanding Global Change* (701-0016-00L), students learn to reflect on concepts, methods, arguments and knowledge claims about global change by analyzing philosophical and scientific papers on computer simulations.
  "There have been few courses in my studies in which I've learned so much regarding precise argumentation and critical reflection on methods and scientific research questions."
- In *Readings in Environmental Thinking* (701-0019-00L), students engage in the discussion and evaluation of key texts in the environmental movement and the environmental sciences.
  "Somehow it opened my eyes to perceive some environmental issues differently and become more critical towards established knowledge or pre-conceived ideas. The key is to develop one's critical thinking and also to be able to put oneself in the place of other people with different ideas and interests in environmental issues."

a *http://hochschuldidaktik.medioag.ch*

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5 Detailed descriptions can be found in the course catalogue of ETH Zurich: *www.vvz.ethz.ch*.