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ABSTRACT BOOKLET

INTERPLAY OF DOMAIN-SPECIFIC AND DOMAIN-GENERAL ASPECTS OF SCIENTIFIC REASONING AND ARGUMENTATION SKILLS

International Workshop organized by Prof. Dr. Frank Fischer (CAS Senior Researcher in Residence), Prof. Clark Chinn, Ph.D. (Rutgers/CAS Fellow), Katharina Engelmann, M.Sc. (LMU Munich) and Prof. Jonathan Osborne, Ph.D. (Stanford/CAS Fellow).

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Keynote:

Why Reason? Inference, Reasoning, and Education

Paul Thagard (University of Waterloo)

It is often assumed that inference and reasoning are the same process, but they are actually very different. Inference is a neural process that is private, parallel, multimodal, emotional, unconscious, fast, and automatic. Reasoning, in contrast, is usually public, serial, verbal, dispassionate, conscious, slow, and deliberate. So the contributions of reasoning to inference are unclear, and it is legitimate to ask why people including teachers should bother with reasoning at all.

Domain-Specificity in the Practices of Explanation, Modeling, and Argument in the Sciences

Susan Goldman (University of Illinois at Chicago), Mon-Lin Ko (University of Illinois at Chicago)

At a general descriptive level science argument can be defined by structural descriptions in the form of claims supported by evidence warranted by principle-based reasoning. This same structural definition can be applied to argument in other disciplines. However, general level description masks important and fundamental differences in argumentation between science and other disciplines (e.g., history, literature) as well as differences among subdisciplines in science. These differences are intimately related to variations within the sciences and across disciplines in the nature of knowledge and how knowledge is generated, the representations that convey information, and the oral and written discourse structures used to communicate ideas. Understanding these differences is fundamental to understanding the nature of argumentation and explanation in the sciences, as well as in other disciplines. We argue that these differences necessitate domain specific analyses and accounts. Through comparative analyses of information resources within the sciences (e.g., models in the life sciences versus models in the physical sciences – chemistry in particular) and between the sciences and the social sciences and humanities, we provide support for our claims about the limitations of general level accounts of argument and the need for domain specific levels. Instructional implications include the need for domain specific approaches to conceptualizing what students need to know and teaching resources that support them in learning it, including professional development that provides opportunities for teachers to examine and deepen their own understanding of argumentation, explanation, and their assessment in the sciences.

Scientific Reasoning in Elementary and Preschool Children. Early Competencies, Cognitive Correlates and Functions for the Acquisition of Domain-Specific Knowledge

Beate Sodian (LMU Munich)

While scientific reasoning skills have traditionally been described as developing only in adolescence, recent research has found strong evidence for a basic understanding of hypothesis-testing and evidence-evaluation in elementary- and even preschool children. The present paper will focus on the developmental origins of scientific reasoning (in the sense of „intentional knowledge seeking“, Kuhn & Franklin, 2006), and relate early scientific reasoning to the development of Theory of Mind and metacognition, as well as to inhibitory control. Furthermore, we will show that domain-general scientific reasoning skills are important for domain-specific inquiry processes even in young children.

Construing Scientific Evidence: The Role of Disciplinary Knowledge in Reasoning with and about Evidence in Scientific Practice

Ala Samarapungavan (Purdue University)

Psychologists and educators have long emphasized the development of evidentiary reasoning as a key component of epistemic competence in the context of learning and doing science. Despite this historical concern with evidentiary reasoning, there is still much that we do not know about its development in science learners, especially in the context of more advanced science learning. Decades of research show that students do not fully understand the nature, quality, and scope of the evidence on which advanced science concepts are founded. In this paper I argue that the pervasive difficulties experienced by many science learners stem, at least in part, from undifferentiated and simplistic notions evidence, divorced from deep disciplinary knowledge and practice, embodied in science curricula. Knowing what counts as evidence with regard to some set of knowledge claims, to what extent, and why, requires the integration of disciplinary knowledge about theoretical principles and inquiry practices. It requires knowledge of relevant variables and plausible mechanisms, how variables are typically operationalized in investigative designs, norms and standards for the precision and accuracy of instrumentation, experimental procedures, and measurement, bandwidths and density of sampling, models for aggregating and analyzing data, and conventions for communicating results. Drawing from examples in biology, I propose that in order to support sophisticated epistemic reasoning in the teaching and learning of science, educators must unpack the notion of evidence itself and reconnect it to its disciplinary contexts.

Domain-Specific Aspects of Reasoning and Argumentation: Insights from Automatic Coding

Iryna Gurevych (TU Darmstadt), Johannes Daxenberger (TU Darmstadt), Andras Csanadi (LMU Munich), Christian Ghanem (LMU Munich), Ingo Kollar (University of Augsburg)

Recent advances in the fields of machine learning and natural language processing (NLP) allow analyzing scientific reasoning and argumentation by means of automatic coding. As opposed to manual coding, automatically generated codes can be applied with low effort at large scale, and to a broad range of domains. This advantage, however, usually comes at the cost of a decrease in validity as compared to expert codings. In this chapter, we report on automatic coding experiments investigating scientific reasoning and argumentation in different domains and discuss the implications for research and practice. Particularly, we model argumentation and reasoning in a data-driven fashion and look at the results of the automatic coding methodology with respect to scientific reasoning and argumentation in certain domains. To this end, we perform our experiments on German datasets reflecting different models of argumentation and reasoning and skill levels. The data types encompass news text, think-aloud protocols and collaborative discourse of teacher students, as well as think-aloud protocols of social work students and professionals. We report results from both in- and cross-domain experiments, effectively modeling the impact of the underlying domain and skill level on automatic coding. For the detection of relevant linguistic signals in the automatic coding pipeline, we apply a range of NLP techniques, covering semantic, structural and lexical information. Our results show that, from the perspective of automatic coding, domain-specific factors have significant impact on reasoning and argumentation. While the same linguistic signals can be used to automatically code scientific reasoning and argumentation in very different domains, transferring domain-specific knowledge between domains remains very challenging.

Specificity Reloaded: How Multiple Layers of Specificity Influence Reasoning in Science Argument Evaluation

Dorothe Kienhues (Münster University), Eva Thomm (Münster University), Rainer Bromme (Münster University)

Argumentation skills and scientific reasoning are continually discussed as being essential for the 21th century. In our contribution, we will focus on laypeople’s reasoning in science argument evaluation in the context of public understanding of and engagement with science. We will first work out different layers of specificity and make the argument that scientific domains are not only characterized by the ‘mere’ content they deal with (or provide). They furthermore can be characterized (and clustered) by the methods (accepted reliable processes) used, their perceived kind of reality (the ontology of a domain) and the social aspects of science, that is, who are perceived as legitimate producers of knowledge, what are processes of negotiating the standards to gain and justify knowledge. This differentiation offers an analytical approach towards a deeper understanding of domain specificity. The same argument might be evaluated simultaneously against criteria on these different layers of domains specificity. We will use this analytical approach for three phenomena which have been recently observed in laypeople's reasoning about science based claims: We will discuss why people do sometimes prefer fast heuristics instead of deep elaboration, how people switch between whom to believe vs. what to believe strategies and how people reason about conflicts in science. In synthesizing our arguments, we will argue that science argument evaluation quite often may cut across “content only”-characterized domains, but may be nevertheless domain-specific in a broader sense.

Beyond Intelligence and Domain Knowledge: Scientific Reasoning and Argumentation as a Multi-Dimensional Cross-Domain Skill

Frank Fischer (LMU Munich/ CAS Senior Researcher in Residence), Katharina Engelmann (LMU Munich), Ansgar Opitz (LMU Munich), Andreas Hetmanek (TU Munich)

In this chapter we characterize scientific reasoning and argumentation (SRA) with four main claims: SRA is a (1) distinct cross-domain, (2) assessable, (3) teachable and (4) relevant skill.

In the argumentation for SRA as a distinct cross-domain skill we assume (a) an ontology of contents of SRA to illustrate the vagueness of the ”domain” concept and

(b) a hierarchy of skills ranging from very general (g-factor) to highly specific (experimentation in "Crystallographic capture of a radical S-adenosylmethionine enzyme in the act of modifying tRNA"). Concerning (a) we make the point that the label/concept "domain" can be assigned to content on very different granularities on an ontological tree and that we therefore need to replace the currently established dichotomy of "domain-specific" vs. "domain-general" in favor of a continuous conceptualization. Thus, we introduce the idea of "cross-domain" skills. We will further refine this idea by an argument based on (b) presenting a plausibilisation of SRA as a skill less general than "g" and at the same time less specific than highly content-specific skills of experimentation in e.g. "Crystallographic capture of a radical S-adenosylmethionine enzyme in the act of modifying tRNA".

In the remainder of the chapter we argue for the fruitfulness of this approach for teaching and learning by providing theoretical as well as empirical evidence for the remaining three claims: cross-domain SRA skill can be (2) reliably measured, (3) effectively taught and used, and (4) successfully applied to a variety of different contexts. In our view this characterization helps to close the gap between very early development of rudimentary SRA in children and highly advanced SRA in international research communities. Finally, we broaden the perspective and develop a proposal for a research agenda to further establish the concept and fruitfulness of cross-domain SRA skills.

General versus Specific Epistemic Cognition: What – if any – Benefits Arise from General Knowledge?

Clark Chinn (Rutgers/CAS Fellow)

Much research examines the question of the domain generality versus domain specificity of cognition by examining whether a general strategy or schema learned in one context transfers to another context. In contrast to some claims about the impossibility of transfer, we acknowledge that such transfer of general knowledge occurs and is regularly demonstrated in educational and psychological research.

In this chapter, we look at this issue from a different angle--one that has been relatively neglected by researchers. We ask not whether knowledge can be shown to transfer (we agree that it can), but whether it can transfer in any useful way for the real world--and if so, what is needed for useful transfer. We focus our analysis on epistemic knowledge, drawing on the AIR framework of epistemic cognition (Chinn et al., 2014; Chinn & Rinehart, in press; Duncan & Chinn, in press).

Our first argument is that only intermediate levels of generality can transfer usefully, and such general knowledge may even be necessary for transfer. Our second argument is that one can transfer epistemic knowledge usefully to solve problems only if one has detailed knowledge of both content and methodologies of the transfer domain, in addition to more general forms of knowledge. What one does gain from more general knowledge is an ability to interact with domain experts in the target domain and to ask useful questions in these interactions, possibly even questions that aid the domain experts (Collins; cf. Walton). But one cannot successfully achieve epistemic ends as an independent epistemic agent without domain-specific knowledge. One implication of our argument is that more rigorous transfer tests reveal the limitations of transfer that we discuss. We propose that most transfer measures are not designed to capture negative transfer that will often occur in transfer to more authentic tasks; further, more realistic tasks will likely reveal limitations to transfer that are not revealed in most published transfer assessments, even those that are billed as measuring "far" transfer.

Another implication is that there is a limit to epistemic agency; a main outcome of learning to engage in inquiry effectively is that one learns why to trust experts who engage in such inquiry practices. There are limits to the efficacy of individual epistemic agency in domains in which one lacks content and methodological knowledge.

In the Eye of the Beholder: Domain-General and Domain-Specific Reasoning in Science

Leona Schauble (Vanderbilt University)

This chapter explores questions about the relative advantages and disadvantages of regarding scientific thinking in young children through a domain general perspective or through a domain specific lens. We are particularly interested in how these differing views influence educational practice in the elementary grades.

Domain-general frameworks are critical for helping policy makers and educators achieve analytic purchase on goals for science learning. They steer the field toward a clear vision of "what develops" and propose answers to the question: What is it, beyond content knowledge, that students should come to understand over the 12 years of their science education (Ford & Forman, 2006)? A vision responsive to this question needs to be shared by stakeholders at all levels of the educational system if instructional goals, content, and tasks are to cumulate toward desired endpoints.

However, the need for this focus at the planning level does not necessarily imply that instruction should be oriented toward requiring students to learn and explicitly apply heuristics and strategies derived from these frameworks. For elementary school students, who are just receiving an initial introduction to the goals and practices of science, it may be more productive in the long run to begin with a bottom-up approach, in which students first become acquainted with science as a modeling enterprise. Modeling immerses students in two critical forms of activity: creating the conditions to know more about the material world and reflecting on how we came to know it (Manz, 2015b). In comparison to more typical school science approaches, which often emphasize logical relations between data and theories, modeling approaches to science turn the spotlight on a fuller panoply of activities involved in creating conditions to know, activities that are often effaced in school science. Because it evokes variability in student solutions, modeling also generates conditions for developing and appreciating scientific argument. Rather than authoritative rules that guide scientific activity prospectively, domain-general criteria and heuristics emerge from students' activity, initially as proposed by and negotiated among students, and eventually, as consensually ratified outcomes of students' work.

Historical Reasoning: The Interplay of Domain-General and Domain-Specific Aspects

Carla van Boxtel (University of Amsterdam), Jannet van Drie (University of Amsterdam)

In this paper we explore the question of domain-general and domain-specific aspects of reasoning in history. Historical reasoning is a form of informal reasoning. There are no single procedures to reach a conclusion and there is no single clear-cut or correct solution. History deals with events that already happened, in a time that is different from ours. This has important implications for reasoning. In order to construct a historical explanation one needs to explore the historical context, identify actions and motives of people in the past, but also developments and societal structures as potential causes and describe how these causes 'produced' the event under inspection. Claims and conclusions about historical phenomena need to be supported by evidence. Historical evidence, however, is often mediated through other people (living in another time), incomplete and uncertain.

Reasoning might be domain-specific because it is strongly determined by declarative and procedural knowledge which is unique in a discipline, or because the reasoning tasks are unique. Domain-specifity can also be the result of the fact that it appears

within a particular epistemic domain. Each domain has its own means and standards of justification.
Using insights from both philosophy of history and history education research, we discuss reasoning tasks that are considered characteristic for the discipline of history. For each type of task we address the question how researchers conceptualize the role of domain-specific declarative, procedural and epistemic knowledge. We will illustrate the interplay of domain-general and domain-specific aspects with examples from students' reasoning in the context of collaborative learning tasks.

Styles of Scientific Reasoning: What Can We Learn from Looking at the Product not the Process of Scientific Reasoning?

Jonathan Osborne (Stanford/CAS Fellow)

In this paper, I advance the argument that what to teach about scientific reasoning has been bedeviled by a lack of clarity about the construct. Drawing on the insights emerging from a cognitive history of science, which looks at the products rather than the process of scientific reasoning, it will be argued that a conception of scientific reasoning based on six ‘styles of scientific reasoning’ offers better insights into what should be taught about science and scientific reasoning. Each ‘style’ requires its own specific ontological and procedural entities, and invokes its own epistemic values and constructs. Previous attempts to develop a coherent account of scientific reasoning have neglected the significance of either procedural knowledge, epistemic knowledge or both and overemphasized the role of experiment and hypothetico-deduction. In contrast, ‘styles of reasoning’ recognize the need for all three elements of domain-specific knowledge, the complexity and situated nature of scientific practice, and the variety of scientific thought. In addition, ‘styles of reasoning’ offer science education a means of recognizing the intellectual and cultural contribution that the sciences have made to contemporary thought, an argument missing from existing accounts of scientific reasoning and a way of giving meaning to the scientific experience for students. Thus, the construct of ‘styles of reasoning’ offers a more coherent conceptual schema for the contruct of scientific reasoning – one of the major goals of any education in the sciences – and something which domain-specific accounts have notably failed to do.