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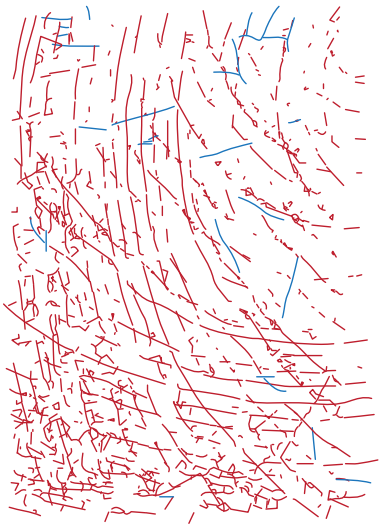

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About the author:

Moritz Epple is a principal investigator at the CRC 1095 *Resource Regimes and Discourses of Weakness* and a professor of history of science at Goethe University, Frankfurt am Main.

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Goethe-Universität Frankfurt am Main
Sonderforschungsbereich 1095 *Schwächediskurse und Ressourcenregime*
Postadresse: Postfach Juridicum 104 | 60054 Frankfurt
Besucheradresse: Gräfstraße 78 | 60486 Frankfurt
Tel.: + 49 (0) 69 798 33952

www.sfb1095.net
info@sfb1095.net

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The Theaetetus Problem: Some Remarks Concerning a History of Weak Knowledge[1]

Moritz Epple (Frankfurt am Main)

1 History of Science as a Historiography of Strength?

The beginnings of the historiography of science in early modern Europe have been informed by a historical narrative in which science – as a body of knowledge, as a cultural tradition, or as a web of institutions – was placed in a position of epistemic, cultural and, eventually, social strength. As is well known, for 18th century historians of the exaxt sciences such as Jean-Etienne Montucla and others, the progress of the exact sciences, and of astronomy in particular, served as an exemplar for the progress of reason and of the human mind.[2] Others, including Jean D'Alembert in his *Discours préliminaire* (1751) to the *Encyclopédie* co-edited by Diderot and himself, and later Nicolas de Condorcet in his *Esquisse d'un tableau historique des progrès de l'esprit humain* (published posthumously in 1795[3]), went a step further and declared the progress of knowledge to be a crucial factor in and a measuring rod for social progress in general.[4] States in which care was given to the advancement of knowledge were considered as far superior to those deplorable kingdoms in which ignorance ruled. When several decades earlier, Voltaire had declared in is *Lettres sur les Anglais* of 1734 that a scientist such as Isaac Newton, and not a violent political leader was the greatest human being of all times, he had not triggered laughter but – in cooperation with a group of like-minded intellectuals and patrons – a Newtonian fashion which, in some senses, continues to this day.[5]

In those "modern" societies which have formed since then, and in particular, in the European nation states of the 19th century and all those later states that have been based on this model, the sciences are organized as a strong arrangement of institutions from elementary schooling to high-prestige research, deeply shaping social and technological life. The main product of this institutional arrangement – *knowledge* – thereby acquires a strong and constitutive role in such societies. Historians have been tempted

1 The following remarks will be published as an introduction to the volume *Weak Knowledge: Forms, Functions, and Dynamics*, edited by Moritz Epple, Annette Imhausen, and Falk Müller, Frankfurt/Main: Campus, 2018. They arose from methodological discussions within the history of science subgroup of SFB 1095 "Discourses of Weakness and Resource Regimes" at the University of Frankfurt/Main. Members of the group were Theresa Dittmer, Nadine Eikelschulte, and Annette Imhausen in ancient science; Christian Forstner, Lukas Jäger, Falk Müller, Linda Richter and myself in modern science.

2 Jean Etienne de Montucla: *Histoire des mathematiques*. 2 vols., Paris: Jombert, 1758. Among the histories of astronomy of the period one should mention Pierre Estève: *Histoire générale et particulière de l'astronomie*. Paris: Jombert, 1755; Jean Sylvain Bailly's contested writings; and, one generation later, Jean-Baptiste Joseph Delambre's *Histoire de l'astronomie* in several volumes, Paris: Courcier, 1817-1827. This narrative was not new in the 18th century. An early praise of astronomy as a result of long-term epistemic progress was given by Johannes Kepler in his *Apologia pro Tychone contra Ursum*, see Nicholas Jardine: *The Birth of History and Philosophy of Science: Kepler's 'A Defence of Tycho against Ursus' with Essays on its Provenance and Significance*. Cambridge: Cambridge University Press, 1988.

3 The *Esquisse*, written shortly before Condorcet's death, summarizes drafts and fragments on which Condorcet had worked for years, cf. Nicolas de Condorcet: *Tableau historique des progrès de l'esprit humain: Projets, Esquisse, Fragments et Notes (1772-1794),* ed. by Jean-Pierre Schandeler and Pierre Crépel. Paris: Institut National d'Études Demographiques, 2004.

4 For an illuminating discussion of the idea of progress and its decline cf. Georges Canguilhem: "La décadence de l'idée de progrès." *Revue de métaphysique et de morale* 92 (1987), 437-454.

5 Compare, among others, JB Shank: *The Newton Wars and the Beginning of the French Enlightenment*. Chicago: University of Chicago Press, 2008.

to speak of societies modeled on these states as "knowledge societies." Scientific and political discourses which aim at stabilizing and extending this position of strength, and historical discourses contributing to a politics of memory which celebrates the sciences as a unique modern achievement, are so widespread that they are hard to survey. Even certain recent and sophisticated forms of professional history of science are still feeding on this narrative of strength.[6]

The narrative is mirrored, and to some extent prefigured, in the philosophical tradition that has addressed the topic of knowledge since antiquity. One *locus classicus* of this tradition is Plato's dialogue *Theaetetus*, offering the philosophical definition of knowledge that probably remains its most widely discussed definition in philosophical circles, and according to which knowledge is a belief (gr. *doxa*) endowed with two additional features providing strength, i.e. *truth* or *correctness* (gr. *orthe doxa*), and a *justification* (*gr. logos*) for the truth of the given belief. The argument of Plato's dialogue consists in a graded criticism of *deficient* forms of knowledge or beliefs: pure sense perception, belief without a truth-check, and correct belief without justification. Plato's text is radical and consistent in its refusal to even call such deficient forms of believing "knowledge". And while modern philosophical interpreters differ widely with respect to the specific meaning to be given to the individual elements of the conception of knowledge offered by the *Theaetetus*, there is widespread agreement that the conception's general structure should be defended.

2 The *Theaetetus problem*

From these and similar theoretical approaches to knowledge, a problem emerges for the historian of science which I will call the *Theaetetus problem:* Can and should the history of science be based on such a demanding and openly normative conception of knowledge (whatever specific version one might prefer)? Some care is needed to frame the *Theatetus problem* in the right way and to clarify what it entails and what it does not. Among other things, it needs to be distinguished both from standard philosophical arguments about the interpretation and validity of Plato's conception of knowledge and from the quest for a sociological approach to knowledge.

First of all, if we consider a text such as Plato's *Theaetetus* as a historical trace, and if we understand the conception of knowledge described in it as a time-dependent, situated conception with its specific ancient Greek motives and functions, the *Theaetetos problem* disappears of course. Few historians of science would feel bound today by the specific normativity ascribed to the knowledge described, e.g. in Plato's curriculum in his *Republic.* Quite obviously, the Athenic philosophers searched for a normative conception of knowledge, and they did so for interesting and complex reasons.[7] A famous Greek parallel to the *Theaetetus* was Aristotle's opening of book *A* of his *Metaphysics* which sought to characterize *episteme*

6 This is even the case in varieties of the history of (scientific) knowledge such as literature on the "science question in feminism" or on "colonial science." When "modern" or "Western" science is characterized as an instrument of male or colonial domination, the assumption rests in place that this instrument is powerful and can serve its purpose on the grounds of this strength.

7 Cf. for instance the discussion by Geoffrey E. R. Lloyd: *Magic Reason and Experience: Studies in the Origin and Development of Greek Science.* Cambridge: Cambridge University Press, 1979.

as a particularly demanding form of knowledge, superior to other forms of knowing such as artisanal knowledge or medical experience.[8] Some of the papers in this volume will touch upon related issues in ancient science.

Now we may go through history and look for comparable articulations of strong, normative conceptions of knowledge, be they philosophical, historiographical, or expressed by scientists of any kind, and we will of course find many instances. Let me just mention the prefaces of Kant's *Critique of Pure Reason,* where (in the preface to the second edition) he repeatedly suggested that the *"sichere Gang"* – a literal translation would be the *secure gait* – of cumulative progress in a given body of knowledge was the characteristic feature of scientific knowledge (according to him, this secure gait was not yet attained in metaphysics nor in several domains of knowledge about nature). In other places, Kant famously mentioned *mathematics* as the essential ingredient of true scientific knowledge. („Ich behaupte aber, daß in jeder besonderen Naturlehre nur so viel eigentliche Wissenschaft angetroffen werden könne, als darin *Mathematik* anzutreffen ist."[9]) Or let us recall the conceptions of science and knowledge advanced by the various forms of positivism of 19th century French or 20th century Viennese variety, or finally, the many and diverse conceptions of knowledge which, while being only half-way articulated or fully implicit, were endorsed by scientists in different times and places in their actual practice…

In a certain sense, different philosophical interpretations of, and reactions to, the *Theaetetus* provide very similar, additional material for a history of the conceptions of knowledge. Some of these have been simple variations of the list of criteria for knowledge given by Plato, such as Alwin Goldman's proposal to denote mere true belief (disregarding justification) as "weak knowledge."[10] Others have aimed for a reinterpretation of one or several of these criteria, in particular, trying to give modified accounts of what it means to justify a given belief. Similarly, any later philosophical framing of the idea of knowledge has found its variety of modern interpretations. As will be seen shortly, such proposals do not resolve the problem posed here.

Indeed, we cannot easily make the Theaetetus problem disappear in a historicist or philosophical way by pointing to a plurality of different notions of (scientific) knowledge. The history of science, and the history of knowledge more generally speaking, cannot escape the question of *which* conception of knowledge should be chosen as the basis of its historiography, for the simple reason that it needs to decide what should be inlcuded within its domain, and what should remain outside. Of course, this question has been asked before, and here, finally, we need to address the traditions of a sociology of knowledge who have called for a radical reframing of the notion of (scientific) knowledge since several decades. The Edinburgh approach, in particular, has asked us to treat belief systems of different historical and/or social origin in an *impartial* and *symmetric* fashion, methodically avoiding to let "truth" or "falsity" of beliefs enter any explanation of why a belief system has been endorsed as knowledge in a particular

8 This demanding notion of *episteme* is further developed in Aristotle's methodological writings, in particular in his *Posterior Analytics*. Wolfgang Detel has argued that in also these considerations a central role is played by a reflection on the deficiencies of human cognitive capabilities, cf. the introduction to Aristoteles: *Zweite Analytik/Analytica Posteriora*, Greek and German, ed. by Wolfgang Detel. Hamburg: Meiner, 2011.

9 Immanuel Kant: *Metaphysische Anfangsgründe der Naturwissenschaft*. Riga: Hartknoch, 1786, A VIII.

10 Alvin I. Goldman: *Knowledge in a Social World*. Oxford: Oxford University Press, 1999.

social configuration, and considering "justifications" to be social phenomena that *require* (sociological) explanation rather than *providing* it for the knowledge in question.[11]

However, truth and falsity and the validity of justifications are not the only topics raised by the *Theaetetus* problem. Rather, it brings to the fore the problem of a gradation, or a hierarchy of more or less *deficient* forms of what is – in one way or the other – considered to be knowledge. This feature is shared by most if not all conceptions of knowledge that we can identify in the historical record. Indeed, even in the *strong programme*'s approach to knowledge, a closer look reveals a gradation of more or less deficient forms of knowing. Let me quote David Bloor's famous passages exposing the *strong programme* in his *Knowledge and Social Imagery*:

> "Of course knowledge must be distinguished from mere belief. This can be done by reserving the word 'knowledge' for what is collectively endorsed, leaving the individual and idiosyncratic to count as mere belief."[12]

Thus, and quite consistently in Bloor's programme, it is the *degree of collective recognition* of a given belief that decides about its status in the hierarchy of knowledge. The Theaetetus problem thus reappears in modified form: Can and should a historical sociology of (scientific) knowledge accept the restriction implied by Bloor to study beliefs endorsed by (large) collectives, or, in other words, to knowledge which has at least *some* strength in social respect?

Similar arguments can be made with respect to proposals such as the one made by Helga Nowotny and coauthors to distinguish "epistemically robust" knowledge from "socially robust knowledge"[13], or any other recent approach to the sociology of knowledge. What all such approaches offer are alternative versions of a *gradation* between stronger and weaker forms of knowing, framed in a specific – here: sociological – way. For Nowotny, to provide social robustness to modern expert knowledge is a *normative* stance, intended to strengthen the democratic legitimacy – and social efficacy – both of certain bodies of knowledge and of the procedures by means of which they are obtained, and it was crucial in her analysis that some bodies of knowledge did *not* possess the robustness she asked for.

The *Theaetetus problem*, therefore, lies deeper than the transition from a traditional epistemological conception of knowledge to a historicist or to a sociological one. It is one task to distance oneself as a historian from normative conceptions of knowledge framed in particular historical situations, and to transform them from unreflected starting points of historiography into objects of historical study in their own right. (In this move I fully agree with the sociology of scientific knowledge and historicist methodologies.) But it is *another* task to bring to light the various scales of differences articulated *within* such normative conceptions, between knowledge in the full sense and forms of knowing that were or are considered more or less deficient from the point of view of any such conception. Texts such as the *Theaetetus* or the beginning of Aristotle's *Metaphysics*, but many non-reflexive documents of the history of

11 David Bloor: *Knowledge and Social Imagery*, 2. ed. Chicago: Chicago University Press, 1991, ch. 1.
12 Ibid, 5.
13 Helga Nowotny, Peter Scott, Michael Gibbons: *Re-Thinking. Science: Knowledge and the Public in an Age of Uncertainty*. Oxford: Polity Press, 2001.

science as well, and even Bloor's distinction between "knowledge" and "mere belief" or Nowotny et al.'s degrees of social robustness indicate that together with every conception of knowledge, there usually comes *a gradation and hierarchy of forms of knowledge perceived to be stronger or weaker, or more or less deficient,* which deserves the attention of historians.

The essential question to be asked here is: Does an ambitious conception of knowledge – be it that of the Athenian philosophers, Bloor's or any other – indeed apply to the empirical material in the archive of past scientific activity?[14] To all who have dealt with at least mildly complex episodes in the history of science the answer should be obvious: No, it does not. Against the backdrop of a rigid Platonic conception of knowledge, a large part of what has been passed down as knowledge from earlier times, i.e. a large part of the empirical material of history of science, would have to be sacrificed. On the other hand, also knowledge that was initially only shared by one or very few individuals and that circulated only in very small groups, or knowledge that could not be considered justified, reliable, or socially robust, has been and will be of interest to the history science in many cases.

Let us rephrase these considerations in slightly more formal terms. Let *A* be any characterization of knowledge that appears in history (whether it be articulated explicitly or shared implicitly by knowledge actors at a particular time and in a particular place, or any of its modern interpretations). Then we call a fragment or a body of knowledge *A-weak,* if and only if it appears to be deficient from the perspective of *A*.[15]

This *relative* characterization of the weakness of fragments or bodies of knowledge encompasses rather different cases. A certain knowledge can be *Plato-weak* or *Bloor-weak*, it can be weak in the sense of the Vienna circle, or in the sense of present climatology. Moreover, the status of a fragment or body of knowledge as 'weak' or 'strong' in this sense is never given once and for all, but may change whenever the guiding conception of knowledge within a certain area of knowledge changes over time, or from place to place, or between different groups of actors. A fragment of knowledge may appear to be weak from a *contemporary* or from a *later* perspective, or it may appear to be weak from the standpoint of one conception of knowledge while *at the same time* it appears to be strong from a competing perspective. (A well-known example of the latter situation would be any experimental knowledge gained in a 17th century vacuum pump, evaluated either from a Boylean or, conversely, from a Hobbesian conception of knowledge.[16]) Even within one and the same conception of knowledge *A*, a fragment of knowledge may appear to be *A*-weak in one respect while appearing to be strong in another.

Our central conjecture is that – in stark contrast to the traditional narrative of strength – a very large, and probably the largest, part of knowledge passed down in the history of science has appeared to be weak at least from the perspective of *some* historically relevant conceptions of knowledge. The

14 We may take the notion of the 'archive' here in a wide, Foucauldian sense.

15 A thanks to Kärin Nickelsen for a discussion that made me aware of the usefulness of this clarification.

16 This is one of the main conclusions to be drawn from Schaffer's and Shapin's analysis of the controversy, cf. Simon Schaffer and Steven Shapin: *Leviathan and the Air-Pump: Hobbes, Boyle, and the Experimental Life*. Princeton: Princeton University Press, 1985.

Theaetetus problem in its most general form, then, consists in studying this conjecture and its potential implications for understanding the dynamics of (scientific) knowledge.

For the history of science and the history of knowledge the Platonic way out of this situation is blocked.[17] For several reasons, historians cannot accept the Platonic stance to reserve the term 'knowledge' only for its non-deficient forms, be it in its original Platonic version or in any of its later reinterpretations or alternatives. For one, such a move would fly in the face of the firm conviction of most historical individuals whom we encounter in the history of science and who, as a rule, have defended their beliefs emphatically as knowledge – perfectly independent of all criticism addressed at their knowledge claims by contemporary or later critics, or by today's epistemologists. Moreover, we cannot undo the essential relativization of the notion of knowledge and the corresponding historical relativization of any scale or gradation of deficient forms of knowledge which we find in the historical archive. If we would do so, we would in fact render invisible the historical variety and variation of such gradations which a historical study of weak knowledge aims to uncover.

It should be clear from the previous remarks that the Theaetetus problem is not limited to what we are presently used to call science. Not only does "science" – in whichever form it is defended at a given time and in a given place – denounce other bodies of knowledge not considered to be science, but even within such alternative bodies of knowledge or belief the question of a gradation of weaker and stronger forms recurs both internally and externally – as is for instance the case when, in the agricultural literature of the 18th century, the weakness of the contemporary physicists' knowledge about weather was pointed out, or when in modern alternative medicine the knowledge claims of "school medicine" are attacked in the name of an alternative experience of health.

3 Some examples

In order to illustrate the scope of our central conjecture it will help to briefly mention some examples and types of weak knowledge. Since the present collection brings to the fore a wide range of very different material a general remark and a very small set of examples shall suffice. This will, at the same time, provide occasion to introduce a number of additional terms and tools for a historical analysis of weak knowledge.

The *general* remark is that the examples for weak knowledge are not limited to a few cases of knowledge claims rejected by the various scientific *mainstreams* of different periods and cultures, such as for instance astrology or alchemy in the modern period, or certain forms of divination in antiquity, or alternative medicine in the present. Quite the opposite: they include entire bodies of knowledge which came to great historical fame, such as large parts of medical knowledge in different periods and, in

17 On some interpretations, even Plato refuses to take this road, since he ends the *Theaetetus* in an aporia. Even the definition of knowledge as true belief with justification is rejected by Socrates, which leaves two possibilities: Either knowledge is an even higher, but undefinable form of insight, or we are left with a multitude of deficient forms of knowledge, without ever being able to obtain knowledge in its fullest and purest form. This would resonate with the claim in Aristotle's *Ethics* that true *theoria* is reserved for gods.

particular, knowledge about the causes of diseases, or knowledge about living beings and their internal and external function, or contested experimental knowledge, both early and late modern cosmological knowledge, and so forth. Moreover, one might want to include entire bodies of unwritten knowledge, and/or 'tacit' knowledge, among the forms of weak knowledge in the sense outlined here.

Let me, therefore, take my *specific* examples of weak knowledge from a tradition that has long and often been regarded as closest to a strong ideal of knowledge, i.e. from the mathematical sciences. Even here, examples abound of knowledge that was or is considered weak from at least some perspectives. All the following examples are well-known. They are used here to underline certain features of diagnoses or articulations of weakness to fragments or bodies of knowledge that are of a more general relevance for other cases as well.

To begin with, we may consider almost every statement made in the context of 17th century infinitesimal mathematics as a case of weak knowledge. This is not only true from the perspective of later conceptions of mathematical rigor. Even at the time, many of the statements of infinitesimal mathematics were contested in heated debates about the validity or viability of the many proposed "methods." Here way may think of Descartes' criticism of Fermat's claims, of the debate about Cavalieri's method, or of George Berkeley's fervent attack against the missing proofs and inconsistent arguments of Newton's fluxional method and Leibniz's infinitesimal calculus.[18] The latter attack not only shows a theologian trying to combat disciplinary and ideological competition from mathematicians within the field of 17th century learning. It was equally cogent on an epistemic level – so much so that the Newtonians saw the necessity to compensate for the weakness of their knowledge claims by means of sophisticated supplementary work.[19]

In such cases we find what we will term a *contemporary discourse of weakness* which can be analyzed historically. Taking Berkeley's attacks on the Newtonians as an example, we find that such a discourse consists of articulations or diagnoses of specific weaknesses in a given body of knowledge, or in a set of knowledge claims, which may range from epistemic to social aspects, often combined in ways which aim at increasing the force of an ascription of weakness, e.g. when Berkeley adds the moral insult of being untrustworthy to the epistemic injury of pointing out what he sees as logical contradictions in the calculus of fluxions or in infinitesimal analysis.

When the weaknesses of infinitesimal mathematics were again, but very differently, criticized in the context of the so-called 'revolution of rigor' during the 19th century,[20] and then again from the perspective of 20th century formal mathematics, we are confronted with two different *retrospective discourses of weakness* concerning this body of knowledge. In other words, the perception, articulation and

18 From the large literature on early infinitesimal methods, see e.g. Margaret E. Baron: *The Origins of Infinitesimal Calculus.* Pergamon: 1969; Enrico Giusti: *Boneventura Cavalieri and the Theory of Indivisibles.* Rome: Edizioni Cremonese, 1980; Kirsti Anderson: "Cavalieri's method of indivisibles." *Archive for the History of Exact Sciences* 31 (4) (1985), 291-367; Paolo Mancosu: *Philosophy of Mathematics and Mathematical Practice in the Seventeenth Century. Oxford:* Oxford University Press, 1996); Giovanna Cifoletti: "La méthode de Fermat: Son statut et sa diffusion." *Cahiers d'histoire et de philosophie des sciences, nouvelle série* 33 (1990).

19 See Douglas M. Jesseph, *Berkeley's Philosophy of Mathematics*, Chicago: Chicago Univerity Press, 1993; in particular, the discussion of Colin Maclaurin's extensive efforts to defend Newton's fluxional calculus against Berkeley's criticism by reworking it in a synthetic style.

20 The term "revolution of rigour" seems to have been coined by Imre Lakatos; see the contributions in Donald Gillies (ed.): *Revolutions in Mathematics.* Oxford: The Clarendon Press, 1992.

problematization of weaknesses in a given body of knowledge may itself have a history. In this as in similar cases, this history was closely intertwined with the history of the *knowledge culture* shaping the field or discipline of which the given body of knowledge was a part, here mathematics.

A second example, equally well-known in the historiography of mathematics, makes clear that not only can the specific perception or articulation of an epistemic weakness shift over time, but in fact a certain body of knowledge that has been considered to be exceptionally strong for centuries can suddenly appear to be weak – a change, which was again coupled to a deep change in knowledge culture. Such was the case with geometric knowledge in Euclid's *Elements*. In the first proposition in the first book of the *Elements* it is shown that an equilateral triangle can be constructed on any given line segment. The argument runs as follows: Let *AB* the given segment, then let a circle be drawn about *A* with radius *AB*, and another circle about *B* with the same radius. Then, Euclid assumes, there will be a point where the circles intersect. Let it be denoted by C and let the lines *AC* and *BC* be drawn (the interested reader will easily provide a diagram illustrating the construction). Then *ABC* is the equilateral triangle sought for, as Euclid doesn't fail to prove after the construction with recourse to the definitions, postulates and axioms stated at the beginning of the *Elements*. In his *Vorlesungen über neuere Geometrie* of 1882, the Gießen mathematician Moritz Pasch would declare this proof to be insufficient, since none of Euclid's postulates and axioms guaranteed that the two circles *did* indeed have a point in common.[21] Euclid had passed over this issue (and several others) without any comment. Thus even the simplest, first proposition in this exemplar of a demonstrative science was, in Pasch's eyes, lacking proof. The intended implication was clear: In its traditional form, Euclid's *Elements* were insufficient as a foundation of geometrical knowledge. For centuries, the point raised by Pasch had *not* been questioned at all.

What does this example imply? We could in fact say that here the Platonic conception of knowledge was mobilized against a long-standing paradigm of true knowledge. For Pasch, it was not the truth but indeed the lack of justification that made Euclid I.1 a weak knowledge claim. But for evaluating this ascription of weakness historically, we must understand the requirement of proof, or justification, in Pasch's specifically *modern* sense, and *not* in the traditional form of Euclidean proof. We are thus again confronted with a change in the guiding conception of knowledge. This particular change was connected with the changing role of intuition as a faculty of the mind capable of justifying mathematical knowledge, a capability first partially and then entirely rejected in mathematical culture after the mid-19th century; a change that would have deep and far-reaching consequences in the 20th century.[22] Pasch's diagnosis of an epistemic weakness in Euclid (and we can find a large number of similar examples in the mathematics of this period) thus had a *dynamizing function*: His aim was to argue for a complete restructuring of geometry

21 Moritz Pasch: *Vorlesungen über neuere Geometrie*. Leipzig: Teubner, 1882, p. 44-45.

22 Pasch's argument provides an interesting example of a retrospective ascription of weakness since his criticism revolves about an issue which had been addressed, in general form, already in ancient Greece, when Plato discussed geometrical practices of drawing which, in his view, mixed up sensual perception with knowledge, see his *Republic*, 510. A critique of intuition as a basis for mathematical knowledge is a recurring motive of discourses of epistemic weakness, cf. Hans Hahn: "Die Krise der Anschauung." In: *Krise und Neuaufbau in den exakten Wissenschaften: Fünf Wiener Vorträge*, 1. Zyklus, Leipzig/Wien: Deuticke, 1933; and, taking its cue from this article, Klaus Volkert: *Die Krise der Anschauung: Eine Studie zu formalen und heuristischen Verfahren in der Mathematik seit 1850*. Göttingen: Vandenhoeck & Ruprecht, 1986.

(and of course he believed to have the key for this restructuring in his hands). This connection between *ascriptions of weakness* and *knowledge dynamics* is one of the points of our approach.

My last example is taken from 19th century geometry as well. Let us briefly recall the first systems of so-called non-Euclidean geometry before, say, the year 1868.[23] Both from a later *and* from a contemporary perspective the systems proposed by Janos Bolyai, Nikolai Lobachevsky and a few other geometers in the late 1820s were considered to be epistemically weak. It was unclear whether, and in what sense, they could be considered to be consistent, demonstrated, or true in the sense that they accurately described the structure of physical space, and so forth. However, even more important for our present discussion may be the fact that the beliefs of their authors were not endorsed collectively, not even within a small, conspired thought collective. In other words, their knowledge was, in this period, *Bloor-weak*. It disappeared in a flood of widely shared belief in the truth of traditional, Euclidean geometry, as is easily shown by bibliometric means, and as was acutely felt by the early non-Euclideans.[24]

Again, we find a mobilizing function of this diagnosis of social weakness. Around 1868, it motivated a number of new approaches to the topic, not least the essay by the Italian Eugenio Beltrami with the telling title *Saggio di interpretazione della geometria non-euclidea,* published in 1868. In this essay Beltrami – well aware of the social weakness of the new geometry – sought to develop a new mathematical *interpretation,* in the precise sense given to this word by the author, of the new geometrical ideas within the framework of traditional geometry. He succeeded, but had to pay a price which may not even have been clear to Beltrami himself. In his interpretation, a kind of negatively curved surfaces made their appearance which could no longer be fully represented in space as it was conceived by geometrical tradition. In order to surmount the widely shared disbelief in non-Euclidean geometry, Beltrami (and others following him) opened up an epistemic fissure in the contemporary web of geometric thought which would gradually widen and eventually transform what Gaston Bachelard termed the *esprit scientifique* within geometry.[25]

All three types of example point to different situations in which contemporary or retrospective diagnoses of weakness of a fragment or body of knowledge, and different dimensions of weakness, have played a role, and they point to different dynamic functions that such articulations of deficiencies could have in the production of knowledge.

4 Dimensions of weakness in (situated) knowledge

It is thus time to turn the tables on the forms, functions and dynamics of weak knowledge. Let us ask systematically about the historical roles of fragments and bodies of knowledge – including scientific

23 In 1868, three texts were published which changed the status of this new mathematical specialty: Bernhard Riemann's still unpublished inaugural lecture, held in Göttingen in 1854 "Über die Hypothesen, welche der Geometrie zu Grunde liegen", Hermann v. Helmholtz's essay "Ueber die Thatsachen, welche der Geometrie zum Grunde liegen", and the contribution by Eugenio Beltrami, mentioned above. See, e.g. Jeremy J. Gray: *Ideas of Space: Euclidean, Non-Euclidean, and Relativistic*, 2nd edition. Oxford: Clarendon Press, 1989.

24 Cf. the bibliography given in Paul Stäckel and Friedrich Engel: *Die Theorie der Parallellinien von Euklid bis auf Gauss*. Leipzig: Teubner, 1895.

25 See Gaston Bachelard: *Le nouvel esprit scientifique*. Paris: Felix Alcan, 1934, ch. 1.

knowledge – that have been perceived or criticized as weak from the perspective of one or several strong conceptions of knowledge, including the perspectives of various philosophies, historiographies, or non-reflexive discourses of scientists.

In our group in Frankfurt's CRC 1095 we are trying to make some inroad into this topic both from a systematic point of view, and based on a (small) number of empirical studies on different episodes from both ancient and modern contexts. Throughout, we take as our starting point the conviction that knowledge – at least insofar as we can trace it historically – is never given *per se* but is always given *in situated form*, for specific knowledge actors in specific historical constellations. *Even if* 12x12 may always be 144 (a question that in contrast to the strong programme and some other forms of epistemology we do *not* want to discuss), *knowledge* about this relation is not given trans-historically and ubiquitously. Rather, it is always present in a concrete form, phrased in a specific language, bound to specific circumstances and individuals (producers, distributors, and consumers of knowledge), it is carried by varying forms of material support, culturally interpreted, endowed with social functions, and so forth.

It is surely superfluous to recall these things here. However it may be worthwhile to point out that the notion of 'situatedness' itself is not entirely clear when applied to knowledge. What, indeed, are the features of a historical or social constellation in which a fragment or body of knowledge may be perceived by a group of actors as strong or weak? One of our sub-projects, presently pursued by Lukas Jäger, looks at the various meanings given to the idea of 'situatedness' in the tradition of the sociology of knowledge, in order to explore relevant dimensions in which knowledge can be considered as being historically situated.[26] One of the relevant traditions has tied the notion of 'situation' or 'constellation' to various versions of a description of social position, ranging from Marxist class position[27] to Karl Mannheim's analysis of "social layers" and Edgar Zilsel's distinction of different professional groups as bearers of a specific experience and knowledge (humanists, university scholars, artisans). A second line of thought has considered the human body in its individual development as a site of 'personal' knowledge (the main author here is Michael Polanyi of course, but one may also point to a variety of accounts drawing on psychoanalysis, including Gaston Bachelard's pertinent writings), and there are a number of combinations of these two traditions outlined e.g.,by Norbert Elias and, in particular, by Donna Haraway's more recent defence of 'situated knowledges'.[28]

For our purposes, it is not necessary to limit the analysis to one of these different perspectives in which some given knowledge may be 'situated', just as it would be besides the point to opt for one specific conception of knowledge. Rather, we can conceive of 'situatedness' in any and all of these dimensions, depending on the specific needs of understanding a given historical constellation. *Within* such constellations, knowledge may have been perceived or appeared to be weak. Any diagnosis, or ascription of weakness to a given fragment or body of knowledge is therefore *doubly relative*: both with respect to a

26 For a full account of Lukas Jäger's study I must point the interested reader to his PhD dissertation, in preparation.

27 The point of reference for this view in the early 20th century debates was Georg Lukacs: *Geschichte und Klassenbewusstsein: Studien über marxistische Dialektik*. Berlin: Malik, 1923.

28 Yet another approach to situated knowledge, emphasizing the intertwining of human and non-human elements in what he terms "dances of agency" has been proposed by Andy Pickering. See his contribution to the present volume.

specific standard of knowledge *against* which it is evaluated, and with respect to the specific situation *in* which it is evaluated.

As indicated in the previous section, such a qualification can *either* be a contemporary ascription by historical actors, *or* a *retrospective* ascription by later actors at different times (including, in fact, ourselves as historians and knowledge actors in our own present). Accordingly, when *discourses* about the weakness of a fragment or body of knowledge are concerned, we need to distinguish between *contemporary* or *retrospective* discourses of weakness. Plato's critique of sense perception or his critique of beliefs without justification was a form of ancient Greek discourse on the weakness of certain forms of knowledge. Similarly, Aristotle's remark that medical experience fell short of what he termed *episteme* contributed to that discourse. George Berkeley's criticism of infinitesimal methods, in turn, contributed to a *comparative* form of a discourse of weakness: Theological argument, he claimed, was logically more rigorous than Newtonian or Leibnizian analysis (shaky and inconsistent in his view) – an argument that was intended to raise concerns both on the epistemic level and on the social level of disciplinary power. And so forth.

Looked at in this way, the archive of the history of science contains a wealth of materials from which an analysis of weak forms of knowledge, of the pertinent articulations and discourses of weakness and the historical changes connected with them may begin. This volume brings to the fore a wide range of such materials from different periods and different scientific fields. Based on a survey of such materials, focusing on contemporary and retrospective forms of ascriptions and discourses of weakness, and based on a survey of the various explicit or implicit conceptions of knowledge operative within them, we may hope to develop a more systematic understanding of the possible dimensions of weakness or strength in knowledge – not in the sense of an ultimate, all-encompassing scale on which we can measure the strength and weakness of knowledge, but in the sense of finding recurring patterns in discourses on the weakness of certain fragments or bodies of knowledge in our empirical material.

We include a preliminary grid of dimensions which we have found useful to frame analytic descriptions of historical episodes in which weak knowledge played a role. In the following three dimensions, and a number of subdimensions, weaknesses of knowledge have repeatedly been addressed by historical actors:

1. the dimension of *epistemic weakness*
   a. knowledge with weak rational anchoring (e.g. missing proof or stringent argument, lack of precise vocabulary, …)
   b. knowledge with weak empirical anchoring (e.g. based on problematic forms observation or experiment, …)

2. the dimension of *social and/or cultural weakness*
   a. knowledge supported only by few or socially weak knowledge actors
   b. knowledge with weak institutional anchoring
   c. knowledge with weak cultural embedding

3. die dimension of *practical weakness*
    a. knowledge that lacks usefulness in specific (technical or social) practices
    b. knowledge that lacks embedding in larger technologies pervading society

We expect this grid to be transformed by further historical work. In particular, the subdimensions listed above may prove to be insufficient, or not detailed enough to encompass all interesting forms and dynamics of weak knowledge. However, a brief look at one of the case studies done in our group may illustrate that in historical episodes of some complexity all dimensions outlined in the grid do indeed arise and pose interesting challenges for historical investigation.

Linda Richter's study of knowledge about the weather in German-speaking literature between 1750 and 1850 provides ample material for a history of weak knowledge.[29] Drawing on an analysis of the corpus of writings on meteorological subjects compiled by Gustav Hellmann in the late 19th century, Richter distinguishes three main bodies of knowledge related to the weather: a body of *physical* knowledge aiming at establishing causes and laws of the weather, a body of *semiotic* knowledge giving rules for interpreting a wide variety of natural or artificial signs pointing to the weather that was, is, or will be, and a body of *organic* knowledge taking the weather to be either related to living beings or even a form of life of its own. In each of these bodies of knowledge, perceptions and mutual ascriptions of weaknesses to individual fragments of knowledge abounded.

For instance, when 1837 Heinrich Wilhelm Dove claimed to have found a "fundamental law" of the rotation of winds, others – such as James D. Forbes – were quick to point out that neither the observational basis nor a theoretical argument warranted to speak of a "law" in this case.[30] Similarly, the claims made in the French officer Denis-Bernard Quatremère d'Isjonval's *Aranéologie* of 1798 to be able to draw inferences from spiders' behaviour to the weather of the next two weeks or so were considered to be empirically weak – which did not prevent many scholars of the time to keep spiders in their offices in order to observe any possible relation between their agility and the local weather.

To turn to the social dimension: when physicists of the time admitted that their knowledge about the weather to come was surpassed by the experience of farmers, there was an interesting trade-off between the epistemic weakness perceived by the physicists in their own knowledge and the weakness they perceived in the knowledge claimed by their competitors of lower social status (and hence, they assumed, lower reliability).[31] An institutional weakness, on the other hand, was admitted and deplored in virtually all efforts to make sustained weather observations prior to the existence of standardized, institutionally

29 Again I must point the reader to the forthcoming PhD dissertation by Linda Richter for a full account. For other studies of meteorology before the advent of national meteorological institutions, from a number of related but different perspectives, see Vladimir Janković: *Reading the Skies: A Cultural History of English Weather, 1650-1820*. Chicago: University of Chicago Press, 2000; Jan Golinski: *British Weather and the Climate of Enlightenment*. Chicago: University of Chicago Press, 2007; Katharine Anderson: *Predicting the Weather: Victorians and the Science of Meteorology*. Chicago: University of Chicago Press, 2005; Fabien Locher: *Le Savant et la tempête: Étudier l'atmosphère et prévoir le temps au XIXe siècle*. Rennes: Presses Universitaires, 2008.

30 Heinrich Wilhelm Dove: *Meteorologische Untersuchungen*. Berlin: Sander, 1837, p. iii. Forbes's criticism can be found in his "Supplementary Report on Meteorology" in the *Report of the Tenth Meeting of the British Association for the Advancement of Science held at Glasgow in August 1840*. London 1841, p. 37-156; here p. 108.

31 See, for example, Horace-Bénédict de Saussure: *Essais sur l'hygrométrie*. Neuchâtel: Fauché, 1783, p. 489-491.

supported observational procedures, even in those efforts that provided a certain amount of collected observational data over a certain span of time and space. For an example of a body of knowledge with a weak cultural embedding, Richter points to the tradition of botanical or floral calendars, advocated by Linné and some of his followers, such as Linne's student Alexander Malachias Berger and the Silesian landowner Heinrich Graf v. Mattuschka: While the idea to measure the 'botanical' progress of the year by means of a suitable sequence of flowerings of plants (that would naturally adapt to variations of the weather) may have been both valuable and attractive to a few, it never found broader cultural support in the period considered.[32]

That the practical dimension of weakness was relevant in knowledge about the weather is obvious and expected. Here we find, on the one hand, the admission of the limited practicability of written (and, at times, printed and sold) rules intended to determine the local weather tomorrow from instrumental observations at one's house (a vision endorsed, e.g. in Michael Adelbulner's collection of essays *Kurze Beschreibung der Barometer und Thermometer, auch anderer zur Meteorologie gehörigen Instrumenten, nebst einer Anweisung, wie dieselben zum Vergnügen der Liebhaber, und zum Vortheil des Publici gebraucht werden sollen* of 1768).[33] On the other hand, we may consider the impracticability of processing even small amounts of the large avalanches of printed numbers from weather observations in journals such as the *Ephemerides Societatis Meteorologicae Palatinae* or the later, short-lived *Annalen für Meteorologie, Erdmagnetismus und verwandte Gegenstände* within a (non-existing) national system of weather forecasting at the time.

It may be helpful to emphasize two aspects of the analytic grid just proposed. *First*, the grid allows to study, in any given episode in the history of knowledge, the mutual *dependence*, or in fact *independence*, of these dimensions of weakness. One might be tempted to ask whether the table is intended to show that epistemic strength is often, or always, *coupled with* social or cultural, and practical weakness, or whether there is a pattern of intrinsic historical development that *ends up* with such a coupling. To this question, a historian's reply should be: Whether or not such couplings exist in a given episode is a matter of empirical investigation, and not a matter to be decided *a priori*. Indeed the distinction between the different dimensions of potential weakness is meant to open up a space for such investigations rather than close it by any form of preemptive epistemology. And indeed, case studies such as Richter's indicate that for extended periods, the perceived weaknesses of a given area of knowledge in the three dimensions may be *independent* from each other.

Second, the question needs to be raised what the status of this table is with respect to the distinction between contemporary and retrospective ascriptions of weakness. Is this a pattern that was active in any past discourse on the weakness of knowledge? Or is this just an analytic device based on our own preconceptions that will eventually need to be replaced by a very different one? To this I would

32 Benjamin Stillingfleet translated Berger's text into English and published it in his *Miscellaneus Tracts Relating to Natural History, Husbandry, and Physick: To which is Added the Calendar of Flora*, 2nd ed. London: Dodsley, 1762, p. 229-327. Matuschka's proposal was published as *Anzeige der Beobachtungen, welche dienen können, einen für Landwirthe sehr nützlichen Naturkalender zu verfassen; entworfen für die patriotische Gesellschaft in Schlesien*. Sagan: Lauh, 1775.

33 Adelbulner was an astronomer in Nürnberg and editor of a journal *Merkwürdige Himmelsbegebenheiten*, in which the material of this monograph originally appeared. Adelbulner's monograph went through 3 editions: Nürnberg 1768, Frankfurt/Main and Leipzig 1776, and again in 1781.

answer that it is a bit, and neither, of both. At this point, the proposed grid may be understood as an abstraction from a variety we find in history, i.e. as a pattern of which instances can be found in rather diverse concrete forms in our empirical material. Still, the abstraction may have some value since it points to *recurring* aspects in a wide variety of historical episodes and situations.

5 The *Theaetetus trap* and the dynamics of weak knowledge

Since any of the dimensions of potential weakness in knowledge is obviously related to a corresponding, complementary dimension of strength it might at first sight appear that in the end, our list amounts to no more than an enumeration of all potential deficiencies (epistemic, social, cultural, practical) that proper knowledge has to overcome. And that a historiography of weak knowledge, in the end, might offer nothing but a contribution to a historiography of the heroic overcoming of all these deficiencies, and the deserved failure of all bodies of knowledge that remain weak.

This however, would be a misunderstanding. It would mean to fall into what may be called the *Theaetetus trap* in the historiography of science. The point of a historical analysis of articulations of weaknesses and deficiencies in knowledge is *not* to prepare for the ultimate, total conception or historiography of strong, epistemically, socially and practically robust knowledge, or to consider any belief or knowledge failing to fulfill these criteria just as a preliminary stage or a deficient form of such ultimate knowledge.

On the contrary: The analysis of weaknesses in knowledge must remain based on the doubly relative notion of weakness introduced above, and its objective is to understand the historical role both of diagnoses and discourses of weaknesses in fragments or bodies of knowledge in specific historical constellations, and of the knowledge so described. All ascriptions of weakness, in any of its dimensions, are to be understood as historically constituted, situated perceptions or constructions within a framework of changing conceptions of what constitutes "proper" knowledge (i.e. knowledge without deficiencies), not as objective properties of given fragments or bodies of knowledge. And, to repeat our central conjecture, in a very large class of historical situations, the amount of knowledge that was perceived as weak in an epistemic or social or practical sense outweighed the fragments of knowledge accepted to be strong in *all* these dimensions by far. This alone requires to revise the traditional narrative of strength in the history of science, and to avoid the trap of an assumed teleology. It may also allow to trace, at least in certain cases, the surprisingly strong performance of bodies of knowledge otherwise thought to be weak. In Richter's study of meteorology, the *semiotic* body of knowledge about the weather proves to be a case in point: Even the physicists of the period were forced to admit that despite its epistemic weakness, and despite the comparatively low social position of some if its proponents, a semiotic approach to weather prediction had more to offer to the interested 'public' than their own physical hypotheses on the course of the weather.

Perhaps the most important aim in an analysis of weak knowledge is to understand what the *functions* of these relative weaknesses have been in the dynamics of knowledge in culture at large, and in

society (or, if you prefer, in society/nature). Articulations of weaknesses in knowledge are not only made by the bearers of such knowledge, but also by actors and groups that make use of, or provide patronage for, or offer competing cultural resources to the knowledge in question. A general hypothesis in Frankfurt's CRC is that perceptions and discourses of weakness in historical formations (of *all* kinds, not just when they concern and involve knowledge) are related to change, to historical transformations in specific ways. From this perspective, the question to ask is: how were and are (the perceptions and articulations of) weaknesses in knowledge functionally related to historical change? In which domains? In what ways? Let me conclude, therefore, with a few remarks on knowledge dynamics within the *sciences*, followed by a look at dynamics within *society* and *culture*.

(1) We have learned to appreciate that virtually all *new* scientific knowledge is weak at least for a certain period. In the phase of its emergence it is often volatile and precarious, difficult to stabilize, to communicate, or to justify, it can be tied to actors who are marginal in the scientific communities of their day, it often lacks practical relevance, and so forth. The historiography of *knowledge in the making*, as it has been advocated by many, from Latour's and Woolgar's *Laboratory Life* to the more recent efforts of Hans-Jörg Rheinberger and his group to study the history of experimental systems and *Wissen im Entwurf* has pointed to many aspects of the dynamical role of weak knowledge in the very core of scientific practice.[34]

(2) Second, we can take another look at the historiography of *controversies* about knowledge, especially those in which the *weakness* of knowledge claims was thematic (rather than priority issues or the like). Several famous cases quickly come to mind; the reader may choose her or his favourite example.[35] In such controversies we are not only faced with the *social dimension* of knowledge claims, but often the *epistemic* and *practical* dimensions are involved as well. We could say that in controversies of this kind the weakness of the knowledge in question is a *condition of possibility* for the controversy itself. Since situations of controversy are highly dynamic, we again find a rather general, dynamic role of weaknesses of knowledge.

(3) To move to the role of knowledge in society at large: Here it is particularly interesting to follow those lines of thought that view knowledge as a *resource* of social and material practices and configurations. Just like a precious metal in ore that is hard to mine, knowledge can be *scarce*, or difficult to exploit, as it were, in a given social constellation. Examples of this kind are often found in historical situations in which a *need for knowledge* (or rather, a limitation of available knowledge) is explicitly articulated by actors other than the producers of such knowledge. A well-known case in point would be the group behind the 1714 *Longitude Act*, bringing together the military, politicians, *and* scientists asking for better methods for navigation. In such cases we find a discourse of *weakness* or *scarcity* of knowledge reaching beyond the ivory towers of science, usually revolving around the *practical weakness* of the bodies of knowledge already at hand, and more often than not (and indeed in the case of navigation) this

34 Bruno Latour and Steve Woogar: *Laboratory Life: The Construction of Scientific Facts*. Beverly Hills: Sage, 1979; for the publications of the group around Rheinberger, see: *www.mpiwg-berlin.mpg.de/research/projects/DeptIII_HoffmannWittmann_KnowledgeMaking* (last accessed 30 June 2018).

35 Famous early modern examples would be the controversies about solar spots, about comets, and even the controversies about the system of the world. In all these controversies, the weaknesses of the opponent's knowledge claims were fervently attacked.

practical weakness is not easily or quickly overcome. A similar situation obtains in 18th and 19th century meteorology with respect to the practical desire for weather prediction, be it in the context of maritime transportation or agriculture. Whatever theoretical progresses towards a dynamical meteorology may have been achieved during the 19th century, they did not satisfy the needs for predictive knowledge articulated in seafaring nations. And when Vilhelm Bjerknes eventually offered his differential equations for calculating the weather, they remained difficult to exploit (numerically, based on sound observational experience, and technically) for quite some time.

More recent examples of this kind come to mind when looking at the decision by national governments to invest in the sciences related to aviation since the early 20th century (in fact including meteorology as a resource for aviation during World War I), or at medical knowledge required to treat health issues that are perceived to be of major social relevance. In these and similar cases one finds broad discourses in which the weakness of certain bodies of knowledge is articulated *along with* other weaknesses of a social constellation, be it a state, an industry, or a smaller social unit. The dynamic role of discourses of weakness of this kind may (and often is hoped to) be a mobilization of *other resources* and in particular, resources *for* the production of knowledge in the areas concerned. In other words, we find a constellation of the kind Mitchell Ash has described as one in which knowledge production and other social practices become *resources for each other.*[36]

(4) A fourth, highly dynamical field in which the weaknesses of knowledge play a key role is the cultural *migration of knowledge*. This is true on many levels, and again it is easy to think of relevant examples.[37] Among other issues, there arises the crucial issue of *translation*, both in the literal sense that the receiving language may be unable to render (or interprete) knowledge expressed in the foreign language, and in the more general sense that the *cultural framing* of the knowlegde in migration may be difficult or impossible to transfer from the place of origin to the place of reception. In all these respects, foreign knowledge may be perceived (and criticized) to be weak, engendering a dynamics of knowledge that may or may not transform the knowledge culture of the receiving side. And not least there is the problem, only known too well in our own period: migrants and travelers often are not in strong social positions, hence the knowledge they might bring often is *socially weak,* at least initially.

In all these and many other situations, the dynamical aspects of weak knowledge, and of articulations and discourses of weakness in knowledge, are obvious. Not just the internal dynamics of knowledge may be concerned but the functions and transformative roles of knowledge in society and

36 Mitchell G. Ash: "Wissenschaft und Politik als Ressourcen für einander." In: Rüdiger vom Bruch, Brigitte Kaderas (eds.): *Wissenschaften und Wissenschaftspolitik: Bestandsaufnahmen zu Formationen, Brüchen und Kontinuitäten im Deutschland des 20. Jh.* Stuttgart: Steiner, 2002, p. 32-51; Mitchell G. Ash: "Reflexionen zum Ressourcenansatz." In: *Ressourcenmobilisierung: Wissenschaftspolitik und Forschungspraxis im NS-Herrschaftssystem*, ed. by Sören Flachowsky, Rüdiger Hachtmann und Florian Schmaltz, p. 535-553. Göttingen: Wallstein, 2016.

37 A research group addressing this issue, and, in particular, migrating knowledge between late antiquity, classical Islam, and late medieval Europe is directed by Rivka Feldhay, see: *http://mhc.tau.ac.il/en/category/ migrating-knowledge/* (last accessed 30 June 2018); see also Rivka Feldhay and F. Jamil Ragep (eds.): *Before Copernicus: The Cultures and Contexts of Scientific Learning in the Fifteenth Century.* Montreal: McGill-Queen's University Press, 2017; Londa Schiebinger: *Secret Cures of Slaves: People, Plants, and Medicine in the Eighteenth-Century Atlantic World.* Stanford: Stanford University Press, 2017, and a growing body of further literature.

culture, and, in last consequence – looking at the material practice of both – even in nature as it is transformed by knowledge-based action.[38] In the perspective taken in the previous remarks, both scientific and non-scientific knowledge are often, if not in most cases, encountered as a precarious, unstable, and sometimes scarce resource of social and material practice. They are ingredients of *assemblages* that go far beyond the epistemic dimension. The dynamical roles of their weaknesses, perceived and articulated in many different ways, are varied and complex – be it in situations in which knowledge is employed for the securing and advancement of social formations and power structures such as the modern state, or in situations in which weak and marginal actors are looking for knowledge-based alternatives to the hegemonic structures of their *Lebenswelt*.

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38 Here we may again refer to Andy Pickering's contribution in the present volume.