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Models of science and society: transcending the antagonism

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What is the appropriate place for science in society? Despite the vast literature on the subject, the science–society relation remains a disputed issue. A major reason is that, when we are asking about the right place of science in society, we are actually asking a range of interrelated and hard-to-answer individual questions. These questions include the role of social values in the research process, the neutrality of science in policy, the interplay between evidence and decision-making, and many others. A sensible way to organize these questions —and the set of potential answers—are science–society interaction models (SSIMs). SSIMs reduce the complexity of the science–society relation and provide generic templates for interactions between scientists and non-scientists. However, SSIMs are often used in an unproductive way, namely as antagonistic camps or as representations of real-world actors' beliefs. Focusing on the popular distinction between technocratic, decisionist, and pragmatist models, this paper discusses the strengths and weaknesses of SSIMs. It argues that SSIMs should not, as is often done in the science–society literature, be understood as antagonistic camps or representations of actor beliefs, but as ideal types and heuristics. Building on this interpretation, this paper presents tentative ideas for a reflexive tool that real-world actors can use to assess their fundamental assumptions about science and society.

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Introduction

What is the appropriate place for science in society? Despite the vast literature on the subject, the science–society relation remains a highly disputed subject (Lincoln and Guba, 2000; Millstone, 2005; Hulme, 2009; Skelton, 2021). This is not only due to the many contexts in which scientists and non-scientists interact, e.g. in policy advice (Kowarsch, 2016), science communication (Brossard and Lewenstein, 2010), or stakeholder encounters within research processes (Bremer and Meisch, 2017). Determining an appropriate role for science in society is also difficult because the question itself is overly complex: Should science be autonomous (Wilholt, 2010; Kitcher, 2011)? Can and should research processes be free of social values (Lacey, 1999; Longino, 2002; Douglas, 2009)? Should scientists advocate societal change (Nielsen, 2001; Pielke, 2012)? Does rational action presuppose scientific evidence (Oreskes, 2004; Sarewitz, 2004)? Hence, when asking about the right place for science in society, we are actually asking various interrelated, non-trivial individual questions. Many of these are "deep-seated, normative questions" (Miller, 2001, p. 479), and most of them are "fiercely contested" (Millstone, 2005, p. 11).

A sensible way to organize this complexity are science–society interaction models (SSIMs). By aggregating the manifold aspects of the science–society relation into clear-cut concepts, SSIMs provide generic, easy-to-grasp templates for interactions between scientists and non-scientists. This can be helpful both for scholars who study the science–society relation and for real-world actors (scientists and non-scientists) who engage in science–society interactions. However, as science's ideal role in society is contested, a range of SSIMs is conceivable. Scholars have therefore proposed various SSIM taxonomies, i.e. sets of SSIMs that describe opposing views of the science–society relation (e.g. Gibbons et al., 1994; Lincoln and Guba, 2000; Jasanoff, 2003; Trench, 2008; Hessels et al., 2009; Pielke, 2012; Krishna, 2014; Fazey et al., 2018; Skelton, 2021). One prominent example is the distinction between technocratic, decisionist, and pragmatist models (TDP taxonomy) (Habermas, 1970). While there are many SSIM taxonomies on the market, the TDP taxonomy remains a popular analytical lens, particularly regarding science–society interactions in policy contexts (Weingart, 1999; Brown et al., 2005; Heinrichs, 2005; Millstone, 2005; Lompe, 2006; Hulme, 2009; Gluckman, 2011; Edenhofer and Seyboth, 2013; Kowarsch, 2016).

This paper discusses the benefits and limitations of SSIMs, focusing on the TDP taxonomy. The paper pursues two aims: first, it scrutinizes how SSIMs should be understood from a theoretical perspective; second, it discusses how SSIMs may be of practical use for actors who wish to reflect on their fundamental (or "philosophical") science–society assumptions. The paper argues that SSIMs are valuable for both theoretical and practical purposes. At the same time, however, there is a tendency in the science–society literature that undermines these merits, namely the tendency to interpret SSIMs as antagonistic theoretical camps or as representations of the beliefs and attitudes of real-world actors. The paper argues that these pitfalls can be avoided if we take SSIMs for what they really are: nothing more—and nothing less—than ideal types and heuristics. While similar concerns have been voiced before, both in the context of the science–society relation (Trench, 2008; Martin, 2012; Jahn et al., 2022) and in the context of the philosophy of modeling (Morgan and Morrison, 1999; Giere, 2004; Colyvan, 2013), this view of SSIMs has not been systematically explored in the science–society literature so far. Building on this interpretation, the paper presents some preliminary steps toward a reflexive tool that actors may use to unwrap their implicit assumptions about science and society. The tool involves six dimensions of key questions and a modified version of the TDP taxonomy. The combination of these dimensions and the modified TDP taxonomy describes a conceptual space in which actors can identify, compare and discuss their science–society assumptions in a constructive manner. The results of such a discussion may be used to design, e.g., research projects or advisory processes at the science–society interface.

SSIMs: definition and examples

What is an SSIM?. This section discusses exemplary SSIMs from the literature, with special consideration of the TDP taxonomy. For this purpose, we first need to define the term SSIM:

Definition 1 A science–society interaction model (SSIM) represents the totality of fundamental assumptions that an actor holds regarding the way in which scientists and non-scientists should interact in a given context. SSIMs involve deep-rooted ("philosophical") assumptions about the nature of scientific inquiry and the principles of social order. These assumptions may be explicit or implicit, stronger or weaker, stable or flexible. Relevant contexts include, inter alia, policy advice, science communication, or stakeholder interactions within research processes. Actors may be individuals (scientists, regulators, etc.) or collective entities (institutions, associations, etc.).

While SSIMs have been extensively discussed by scholars of science and society (see the section "Taxonomic SSIMs: examples"), this actor-specific interpretation suggests that an SSIM need not necessarily have an equivalent in the academic literature. That is, a real-world actor can hold certain beliefs on science and society that are, in this particular configuration, not at all discussed in the relevant literature; yet, the actor's set of assumptions is still an SSIM, however implicit or theoretically unarticulated these assumptions may be. SSIMs that are part of a published taxonomy are termed *taxonomic* in this paper, while SSIMs that real-world actors (often implicitly) hold are termed *non-taxonomic*. Also, note that the above definition refers to normative SSIMs. This does not mean that SSIMs do not include descriptive assumptions; however, the SSIMs considered in this paper are normative in that they provide competing answers to the question of how scientists and non-scientists *should* interact. While this paper does not take any position as to which of these answers is ultimately correct, it suggests that it is worthwhile to make the underlying science–society assumptions explicit and discuss them in a constructive manner (see the section "Mapping actor assumptions in the conceptual space: methodological considerations"). Furthermore, this paper focuses on fundamental or "philosophical" (in a broad sense of the word) aspects of SSIMs, acknowledging that actors will often hold these philosophical assumptions in an implicit rather than explicit manner (Hulme, 2009, p. 94; Kowarsch, 2016, p. 82; Crowley and O'Rourke, 2021).

Finally, it is important to avoid two misunderstandings. One misunderstanding would be that terms such as "science–society relation" or "science–society interaction" are meant in a literal or reifying sense. This would be implausible, not only because science is obviously part of society, but also because science and society cannot interact as a whole (only specific actors can do so). Also, there are of course many global societies and many scientific disciplines. Terms such as "science–society relation" or "science–society interaction" should thus not be taken literally, but as a linguistic convention that captures a large variety of interactions between scientists and non-scientists in one simple term.

Another misunderstanding would be that SSIMs are "models" in the same sense as, e.g., the Bohr model of the atom or a general circulation model of the global climate. While these types of models resemble SSIMs by providing stylized representations of a target system (see e.g. Frigg and Hartmann, 2020) and by serving some of the cognitive functions that SSIMs serve (e.g. complexity reduction), they differ from SSIMs in several ways. First, SSIMs are normative rather than descriptive. In this respect, SSIMs are more similar to ideals in moral or political philosophy than to models used in the natural or social sciences. Second, SSIMs are neither predictive nor do they allow for causal inferences. SSIMs can therefore not be "fed with data" to draw conclusions about how a target system may behave under similar conditions. Third, SSIMs are sets of assumptions, but these assumptions are not linked in the same sense in which, say, atmospheric and ocean components of a climate model are coupled. Rather, SSIMs form a *semantic web*, i.e. a network of beliefs that share a conceptual affinity with each other (similar to the affinity that Max Weber famously saw between Protestantism and capitalism). Fourth, SSIMs are not even consistently called "models" in the science–society literature, with terms such as "paradigms" (Lincoln and Guba, 2000), "modes" (Gibbons et al., 1994), "social contracts" (Hessels et al., 2009) or "orders" (Skelton, 2021) offering alternatives that do not evoke the association with scientific models. Despite the similarities that exist between SSIMs and scientific models, it thus seems plausible to treat SSIMs as their own ontological and methodological category.

Taxonomic SSIMs: examples. The question of how science and society should interact has been discussed many times in the academic literature (e.g. Habermas, 1970; Jasanoff, 1990; Gibbons et al., 1994; Guston, 2001; Kourany, 2003; Longino, 2002; Estlund, 2003; Nowotny, 2003; Sarewitz, 2004; Carrier et al., 2008; Brown, 2009; Douglas, 2009; Hoyningen-Huene, 2009; Elliott, 2011; Kitcher, 2011; Edenhofer and Kowarsch, 2015; Bremer and Meisch, 2017). Apart from certain trends, however, the question remains "a fiercely contested domain" (Millstone, 2005, p. 11). Scholars disagree about fundamental issues such as scientific value-freedom (e.g. Douglas, 2009 vs. Betz, 2013) or political neutrality (e.g. Nielsen, 2001 vs. Hagedorn et al., 2019); also, the literature is divided into various disciplines, theoretical approaches, and terminologies. Moreover, the debate is fragmented into multiple thematic contexts such as policy advice (e.g. Jasanoff, 2003; Pielke, 2012), science communication (e.g. Trench, 2008; Brossard and Lewenstein, 2010), or analyses of research paradigms (e.g. Fazey et al., 2018; Skelton, 2021). The "substantial literature" (Millstone, 2005, p. 11) on the science-society relation thus "does not provide anything resembling a single, coherent agreed framework" (Millstone, 2005, p. 11).

Yet despite the differences, the literature features a communality: the use of conceptual oppositions. Popular examples include "tame" versus "wicked problems" (Rittel and Webber, 1973), "issue advocacy" versus "honest brokering" (Pielke, 2012), "normal" versus "post-normal science" (Funtowicz and Ravetz, 1993), and many others. The idea of these concept pairs is that there are fundamentally different ways of doing science and that the question of how science and society should relate to each other can be answered in very different ways. Of course, not all concept pairs in the science–society literature qualify as full-fledged SSIMs. The famous tame-wicked distinction, for instance, addresses the more specific question of how socio-scientific problems should be understood (see also Schmidt, 2011). While this is not *as such* an SSIM in the above sense, such distinctions have implications for the science–society relation at large, e.g. whether or not the public should "entrust de facto decision-making to the wise and knowledgeable professional experts" (Rittel and Webber, 1973, p. 167). Also, these concept pairs presuppose assumptions of a very general kind, e.g. whether there are "value-free, true-false answers" (Rittel and Webber, 1973) in science, or whether society is characterized by a "politicization of subpublics" (Rittel and Webber, 1973, p. 167). These assumptions reach far beyond seemingly narrow questions such as "what is a socio-scientific problem?" (Schmidt, 2011) and touch upon many dimensions that a full-fledged SSIM includes. We can thus take it that, while not all concepts in the science-society literature are SSIMs as such, they have strong conceptual ties with the larger SSIM taxonomies that we discuss in this paper.

A crucial aspect, and a starting point of this paper, is that SSIMs have similar structures and recurring themes. Consider the following examples from different branches of the science–society literature. In the context of science communication, authors have contrasted the "deficit model" with concepts such as the "interactive science model" (Einsiedel, 2000). The former claims that "the public [is] 'deficient', while science is 'sufficient'" regarding knowledge quality (Sturgis and Allum, 2004, p. 57). In contrast, the latter model emphasizes "the uncertainty of scientific knowledge" (Einsiedel, 2000, p. 205) or "the lack of demarcation between scientific […] and other forms of knowledge" (Einsiedel, 2000, p. 205). In the context of research paradigms, Lincoln and Guba (2000) make a similar distinction between "old" and "new paradigm research". The former claims that science should be objective and detached from social practice, whereas the latter holds that "social transformation […] is the end goal [of science]" (Lincoln and Guba, 2000, p. 172), and that research is "incomplete without action on the part of participants" (Lincoln and Guba, 2000, p. 172). In a similar context, Gibbons et al. (1994) have famously distinguished "mode 1" from "mode 2" research. The former is "characterized by the hegemony of theoretical or […] experimental science; by an internally driven taxonomy of disciplines; and by the autonomy of scientists" (Nowotny et al., 2003, p. 179). The latter is "socially distributed, application-oriented, trans-disciplinary, and subject to multiple accountabilities" (Nowotny et al., 2003, p. 179). As we shall see in the next subsection, the sort of assumptions that these distinctions refer to, but also the way in which the assumptions are contrasted with each other, are typical for SSIM taxonomies in the science–society literature. While this paper focuses on the TDP taxonomy, a good part of the following considerations can thus be transferred to other taxonomies and concept pairs in the field.

The TDP taxonomy. Let us now discuss the technocratic-decisionist-pragmatist (TDP) taxonomy. Originally proposed by Habermas (1970), the taxonomy has become a "traditional" (Lompe, 2006) analytical lens for the relation between science and societal decision-making, particularly in public policy (Weingart, 1999; Brown et al., 2005; Heinrichs, 2005; Millstone, 2005; Hulme, 2009; Gluckman, 2011; Edenhofer and Seyboth, 2013; Kowarsch, 2016). The taxonomy is also the basis for the widely discussed "linear" model of expertise, which is largely identical to the technocratic (Beck, 2011) or the decisionist model (Heazle et al., 2016), depending on the interpretation (Durant, 2016). It has also been used as an umbrella concept for both of these models (Weingart, 1999; Lompe, 2006). There are three reasons why this paper focuses on the TDP taxonomy rather than, say, the mode 1/2 distinction. First, the TDP taxonomy is not only one of the most popular SSIM schemes in the literature, but it also looks back on a longer history than other taxonomies. The fact that after more than fifty years Habermas' SSIMs are still "mentioned again and again" (Grunwald and Saretzki, 2020, pp. 12–13, my transl.) makes this taxonomy particularly interesting. Second, the TDP taxonomy is more generic than many dualist taxonomies ("mode 1" vs. "mode 2", "normal" vs. "post-normal science", "old paradigm" vs. "new paradigm research" etc.). One advantage of the TDP taxonomy is therefore that, as Martin Kowarsch has put it, various other SSIMs "can be understood as mere variations or mixtures of the three models presented by Habermas" (2016, p.

85). Third, the TDP taxonomy can be extended beyond its original context, scientific policy advice, such that it includes a range of other aspects of the science-society relation (e.g. science communication or co-productive research, see the section "A modified version of the TDP taxonomy"). Hence, although the TDP taxonomy is but one of many SSIM schemes on the market, it is particularly promising as a starting point for analyzing the science–society relation. The TDP taxonomy comprises three SSIMs[1]:

(T) The technocratic model aims to rationalize society by subverting it to the "objective knowledge of the expert" (Habermas, 1970, p. 63). This includes both the determination of means (technologies, strategies) and ends (practical goals). Science determines means and ends in a value-free manner (Kowarsch, 2016, p. 88). The SSIM hence suggests that "technical considerations are not just necessary but also sufficient for policy decision-making" (Millstone, 2005, p. 14).

(D) The decisionist model aims "to separate strictly the functions of the expert from those of the politician [and the decision-maker more general]" (Habermas, 1970, p. 63). However, this only holds for societal ends, which the SSIM assumes to be value-laden. But once the goals are set by societal actors, the means can and should be determined objectively by science. The SSIM's main features are thus the value-freedom of the research process and a neutral role for science in societal debates (Millstone, 2005; Kowarsch, 2016).

(P) The pragmatist model envisions an iterative process, where science "is governed by a horizon of […] value systems" (Habermas, 1970, p. 67), and where social values are "being tested with regard to the technical possibilities [as identified by science]" (Habermas, 1970, p. 67). While science actively shapes societal goals, it has no unquestionable authority. Rather, fact-finding and norm-setting are interdependent (Edenhofer and Kowarsch, 2015). The SSIM thus rejects both value-free research and the neutrality of science in public debates. The pragmatist model, or versions of it, represents the dominant trend in the current science-society literature (Kowarsch, 2016, p. 91).

As can be seen from these descriptions, the TDP taxonomy addresses similar issues as the distinctions mentioned in the previous section, e.g. objectivity, authority, or neutrality. Even more crucially, these taxonomies have similar structures: First, they typically involve only a few SSIMs (three in the case of the TDP taxonomy). Second, taxonomies describe SSIMs in a rough, schematic way. Some of these schematic descriptions imply strong or even extreme positions (e.g. "scientists should have full decision authority in society"). Third, taxonomies typically assume sharp oppositions between SSIMs, with clear-cut conceptual divides and contradictory views of science and society. This incentivizes a view that will be critically discussed in the next section: the idea that SSIMs describe opposing theoretical camps, and that an actor who subscribes to one taxonomic SSIM will (or should) reject the other taxonomy members. An illustration of the TDP taxonomy and the respective SSIMs is given in Fig. 1.

The problem with taxonomic SSIMs

Taxonomic SSIMs: benefits. This section discusses the benefits and limitations of SSIMs and SSIM taxonomies. It argues that SSIMs can be valuable for both theoretical and practical purposes. However, they also have downsides, at least in a certain interpretation. The section argues that in order to transcend the limitations while keeping the benefits, we should strictly treat taxonomic SSIMs as ideal types and heuristics. While this interpretation is not new in itself, it is obscured by a tendency in the literature to view taxonomic SSIMs as antagonistic camps or as representations of the beliefs and attitudes of real-world actors.

SSIMs and SSIM taxonomies have two basic merits: they reduce complexity, and they illuminate the contestedness of the science–society relation. The first point refers to the complicated character of the science–society relation. For instance, whether science should be autonomous, whether science is superior to other types of knowledge, and what this means for, say, the role of scientists in public debates—are non-trivial questions. SSIMs organize this complexity (in this regard they are similar to models in other contexts, see e.g. Turnbull, 1993; Frigg and Hartmann, 2020). By reducing the range of conceivable views to a manageable number of easy-to-grasp concepts, they provide analytical templates by which scholars can categorize different claims and theories about the science–society relation; real-world actors (scientists and non-scientists), on the other hand, may find it easier to judge the quality of a science–society interaction if they know which options are theoretically conceivable. The most crucial benefit of SSIMs is thus their orienting cognitive function.

The second benefit refers to the controversial character of the science–society relation. Debates about the right place for science in society reach back centuries (Hessels et al., 2009; Martin, 2012; Krishna, 2014) and are unlikely to be settled any time soon. Empirical research also shows that actors disagree on these issues. For instance, Van der Hel (2018) finds that "[s]ome researchers perceive it as not only impossible but also undesirable to separate normative and value-laden questions from […] research", whereas other scientists hold "that researchers should strive for independence and impartiality" (Van der Hel, 2018, p. 256). Discrepancies can also be found between actor groups. Steel et al. (2004), for instance, find that only 16% of researchers in their sample agree that scientists should advocate for specific policies; representatives of interest groups and the public, however, are much more likely to agree with that claim (46% and 36%, respectively, Steel et al., 2004, pp. 6–7). Furthermore, these findings vary strongly across studies (see e.g. Gray and Campbell, 2009; Reiners et al., 2013). SSIM taxonomies make these controversies visible. This helps scholars to identify fundamental differences between competing theories and may support real-world actors in understanding the extent and gravity of potential disagreements in a science–society interaction.

Taxonomic SSIMs: weaknesses. Yet these benefits come at a price. As indicated before, taxonomies of SSIMs tend to be narrow (involving only a few conceptual options), stereotypical (involving undifferentiated and sometimes extreme positions), and antagonistic (involving harsh conceptual oppositions). While these are exactly the properties that make SSIM taxonomies valuable as reducers of complexity and illuminators of conceptual divides, they can also give rise to a limited and antithetical view of SSIMs. Consider the issues of authority, objectivity, and neutrality. The TDP taxonomy presents us with the following alternative:

(T) Scientists should have decision authority, as they possess objectively correct solutions to societal problems.

(D) Scientists should remain neutral, as societal goals are normative and inaccessible to objective scientific analysis.

(P) Scientists should neither have decision authority nor can they remain objective and neutral, as their expertise is deeply value-laden.

We can easily see that the spectrum described by these claims is not very nuanced. Moreover, these claims can create the impression that accepting one SSIM forces us to reject the other

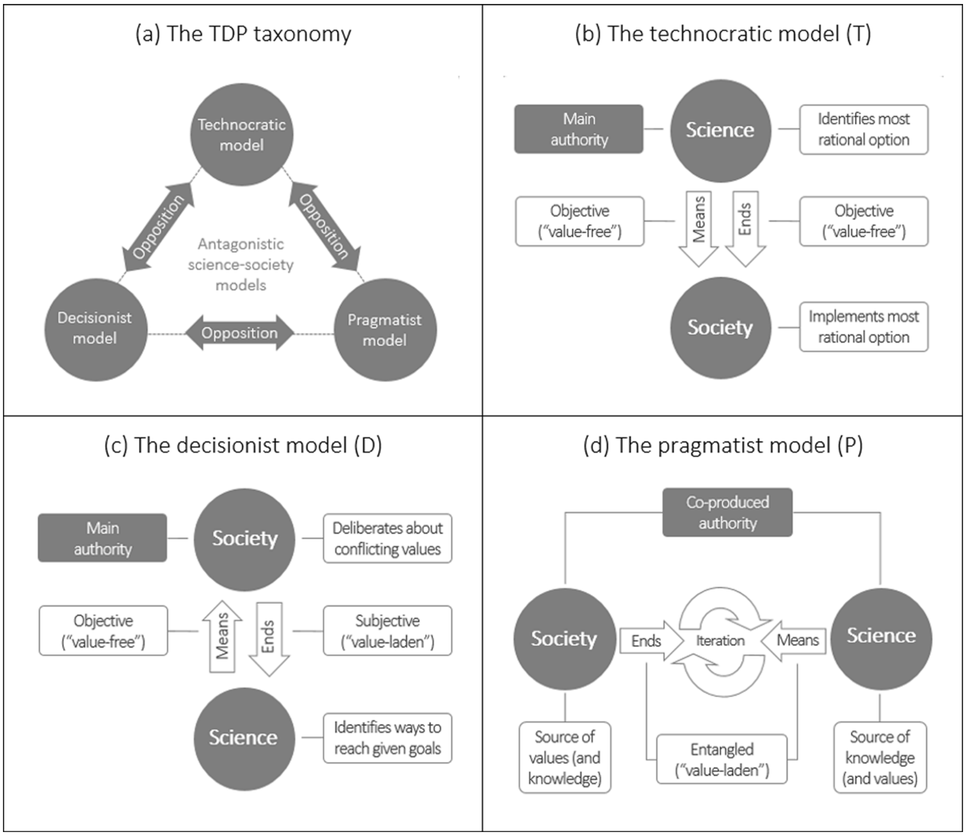

Fig. 1 The TDP taxonomy. The included SSIMs are typically conceived as antagonistic (**a**). The technocratic model assigns a strong decision authority to science (**b**). The decisionist model assigns the main decision authority to society (**c**). In the pragmatist model, the decision authority is co-produced in an iterative exchange between science and society.

two. It may be objected that scholars are well aware of the many middle-ground positions that are possible between these extremes and that consequently SSIMs are not seen as mutually exclusive in the literature. Unfortunately, however, many scholars have embraced exactly this antagonistic interpretation. As Brossard and Lewenstein (2010) have put it: "The literature tends to describe these models as mutually exclusive and to present them as the backbone of different research and outreach paradigms" (Brossard and Lewenstein, 2010, p. 17). For instance, Lincoln and Guba (2000) argue in their influential article on paradigmatic science–society controversies that SSIMs are "incommensurable" (Lincoln and Guba, 2000, p. 172), and that actors cannot "'pick and choose' among the axioms of [opposing] models, because the axioms are contradictory and mutually exclusive" (Lincoln and Guba, 2000, p. 174). While Lincoln and Guba concede that there are overlaps between those SSIMs that are part of one SSIM family, they argue that it is "highly unlikely and would probably even be less than useful" (Lincoln and Guba, 2000, p. 185) that proponents of opposing SSIMs try to "find some way of resolving their differences" (Brossard and Lewenstein, 2010). As a direct consequence of this antagonistic view, many scholars believe that one SSIM—typically a version of the pragmatist model (Pielke, 2012, p. 78; Durant, 2016; Kowarsch, 2016, p. 91)—should straightforwardly replace its competitors. In this vein, critics of the linear model(s) have made it very clear that their aim is not to identify middle grounds and overlaps between SSIMs but to substitute one SSIM with another. Only very rarely have scholars argued that the technocratic and decisionist models should co-exist with the pragmatist model (a notable exception is Durant, 2016); rather, the dominant idea is that the technocratic and decisionist models are "significantly flawed" (Beck, 2011, p. 304), "profoundly mistaken" (Grundmann and Rödder, 2019, p. 9), weak (Habermas 1970, p. 64) or dubious (Habermas, 1970, p. 65), and that consequently these SSIMs should be abandoned once and for all.

The problem with this view is not that the often criticized decisionist and technocratic (or linear) models were actually "true"—in fact, it may not even be relevant whether a taxonomic SSIM is "true" (see the section "Revisiting taxonomic SSIMs"). The problem is rather the underlying idea that subscribing to one taxonomic SSIM means rejecting the other two. Yet in reality, there are many positions that overlap with *all* of the above claims, and these positions are neither internally inconsistent, nor "significantly flawed" or "profoundly mistaken" despite their partial acceptance of claims (T) and (D). For instance, an actor who believes that value-ladenness is inevitable may still hold that values are less relevant in some branches of research than in others. Similarly, an actor may agree that neutrality is not fully achievable in societal debates but still maintain that some styles of scientific advice are more neutral, and thus more legitimate than others. An actor may also believe that science should not hold decision authority in general, and yet hold that technocratic decisions are more legitimate in some cases than in others. These alternatives imply a partial and conditional acceptance of all three of the above claims—obviously without any formal or material contradiction. It is thus misleading to interpret taxonomic SSIMs as opposing theoretical camps that cannot co-exist in a reasonable and consistent way.

Another problem is that the above claims seem to suggest a straightforward link between neutrality, objectivity, and value-ladenness. Yet in reality, a range of positions is conceivable here. For instance, some authors hold that science can be value-laden and yet objective (Harding, 1995; Steel et al., 2017), while others hold that *if* science is value-laden, *then* "[t]he research process can no longer be characterized as an 'objective' investigation" (Nowotny et al., 2003, p. 187). Similarly, some hold that *if* science is value-laden, *then* scientific advice cannot be neutral (Betz, 2013), while others argue that neutrality is a function of high epistemic standards rather than value-freedom (John, 2015). This reinforces the point that taxonomic SSIMs are not mutually exclusive, and that the focus on the conceptual differences between SSIMs can obscure the large spectrum of conceivable middle-ground positions.

It may be objected that these issues are merely theoretical, as taxonomic SSIMs are not meant to guide real-world science-society interactions. But this is not how SSIMs are discussed in the literature. Quite on the contrary, many authors have argued that SSIMs have an "action-guiding character" (Kowarsch, 2016, p. 83) (see also Hulme, 2009, ch. 3.5; Hubbs et al., 2021). Mike Hulme has famously argued that "part of the reason that we disagree about climate change is that there are a number of different models of how science is (or should be) used in policy development" (2009, p. 94) and that "recognizing these different models of science-policy interaction is crucial" (ibid.) for both scientists and policy-makers. A dominant motivation in the literature is therefore to advance science-society interactions by changing the underlying SSIMs (e.g. Habermas, 1970; Jasanoff, 2003; Sarewitz, 2004; Beck, 2011; Pielke, 2012; Grundmann and Rödder, 2019). It is hence safe to assume that academic debates about SSIMs are not purely theoretical but also aim to assist real-world actors (for a practical example, see Felt et al., 2007).

The problem, however, is that the antagonistic interpretation of the TDP taxonomy is not well suited for this purpose. Actors may not find it convincing that SSIMs are "mutually exclusive" (Lincoln and Guba, 2000, p. 174), or that the decisionist and technocratic models are so "profoundly mistaken" (Grundmann and Rödder, 2019, p. 9) that there cannot be a reasonable compromise that also includes some decisionist or technocratic elements. While empirical studies find correlations between actors' assumptions regarding different aspects of science and society (Gray and Campbell, 2009; Reiners et al., 2013; Steel et al., 2017), they do not support the idea that actors are strict supporters of one single taxonomic SSIM. For instance, an actor who believes that science is the only reliable form of knowledge can—but need not necessarily – believe that scientists should make societal decisions (Steel et al., 2004, p. 7). Empirically speaking, actors are typically *somewhat* technocratic in *some* respects and *somewhat* decisionist or pragmatist in *other* respects. This, however, is not reflected by the antagonistic interpretation of the TDP taxonomy.

Is the critique of taxonomic SSIMs old news?. At first glance, the critique that there are many middle-ground positions between taxonomic SSIMs may seem like a truism. Also, one might wonder whether similar critiques that have long been discussed in other contexts, e.g. in scientific modeling (Box, 1979) or regarding idealizations more generally (Turnbull, 1993), have not been considered in debates about the science–society relation. However, several considerations indicate that the apparent truism is not so trivial after all. The first consideration is that, if the critique were indeed a common sense in the science–society literature, one would not expect to find concerns regarding the antagonistic interpretation in this literature. Yet several authors have raised exactly this concern. Sturgis and Allum (2004) contend that scholars have focused too much on extreme versions of the deficit model of science communication and that this taxonomic SSIM is "something of a 'straw man'" (Sturgis and Allum, 2004, p. 57); Trench (2008) argues that the literature has adopted a "bipolar view" (Trench, 2008, p. 130) of SSIMs and that this view is "neither an accurate account of recent developments nor a useful guide to current and future practice and analysis" (Trench, 2008, p. 130); Jahn et al. (2022) maintain that the literature "seems to imply a duality of transdisciplinary [i.e. stakeholder-involving] versus non-transdisciplinary research" (Jahn et al., 2022, p. 2) and that scholars lost sight of the "spectrum of more or less transdisciplinary research modes" (Jahn et al., 2022, p. 2) that we find in reality; Martin (2012) argues that the famous mode 1/2 distinction is often interpreted as mutually exclusive and that in reality, these SSIMs come in mixtures. These remarks indicate that the antagonistic interpretation is indeed widespread; however, one should also note that such remarks are scattered in the literature and have not been systematically explored on a general level.

Another consideration is that, if the above critique were indeed a truism, one would expect that the technocratic and the decisionist models are discussed in such a way that these SSIMs are at least partially acceptable. Also, one would expect scholars to emphasize that there is not typically a full convergence between an actor's assumptions and a taxonomic SSIM. Yet these expectations prove to be false. Rather, the terms "decisionist", "technocratic" and "linear" have long been vehicles to criticize scientists for being ignorant of their own normativity and the nature of politics (starting with Habermas, 1970). Furthermore, scholars have often portrayed actors as exclusive subscribers to one single SSIM. Beck (2011), for instance, has argued that the Intergovernmental Panel on Climate Change (IPCC) "clearly uses the linear model of expertise" (Beck, 2011, p. 298), and Grundmann and Rödder (2019) have argued that "key participants in the climate change discourse operate under the assumption of a linear model" (Grundmann and Rödder, 2019, p. 1). The idea that aspects of the linear model may be worth keeping, or that actors' assumptions are more nuanced than the schematic description of a taxonomic SSIM, is not very typical for these contributions.

This brings us to final consideration. If the discussed critique were a truism, it would be implausible for scholars to anticipate that an SSIM vanishes completely from science–society debates. After all, it seems perfectly acceptable that taxonomic SSIMs coexist if they are not antagonistic and mutually exclusive. Yet there are many complaints in the literature that, e.g., the linear model is "refusing to die" (Durant, 2016, p. 31) despite scholars of science and society "dealing the linear model of expertise innumerable mortal blows" (Durant, 2016, p. 17). A sensible explanation why many scholars find it "puzzling" (Van der Hel, 2018, p. 256) that this SSIM "remains to receive such strong support" (Van der Hel, 2018, p. 256) is that they assume the antagonistic interpretation discussed above. The apparent truism that actors may well support several taxonomic SSIMs at the same time is therefore not so trivial after all.

Revisiting taxonomic SSIMs. The previous subsections have argued that, on the one hand, SSIMs and SSIM taxonomies can be useful for theoretical and practical purposes; on the other hand, however, they can give rise to an unconstructive view of the respective debates. This raises the question of how taxonomic SSIMs can be used in a more constructive manner, thus overcoming the shortcomings while keeping the benefits. Building on the above considerations, a revised understanding should have the following characteristics:

- Wider option space. A revised understanding should allow for more SSIM alternatives, while also reducing complexity in such a way that taxonomic SSIMs retain their orienting function.

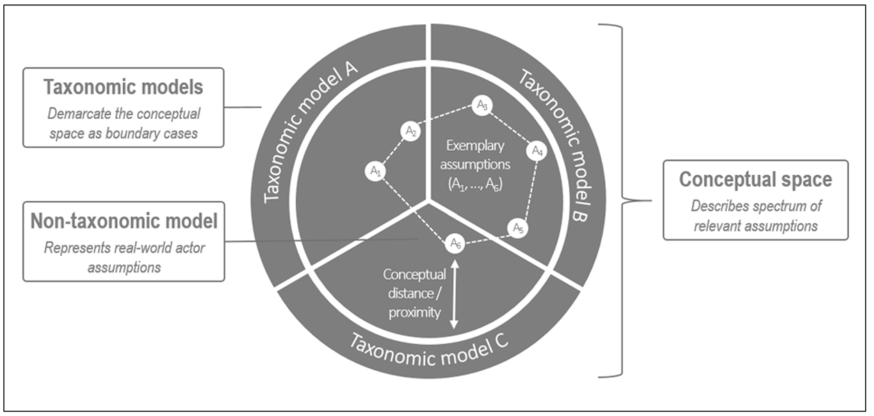

Fig. 2 The conceptual space. Taxonomic SSIMs are used as boundary cases. Real-world assumptions are defined by their conceptual distance/proximity to the boundary cases. Real-world actors will typically hold several relevant assumptions. The totality of an actor's assumptions makes up the actor's non-taxonomic SSIM.

- Non-stereotypical SSIMs. A revised understanding should avoid the impression that actors need to commit to a taxonomic SSIM in its purest (most "extreme") form.
- Non-antagonistic SSIMs. A revised understanding should show how actors can partially accept several taxonomic SSIMs simultaneously, while also illuminating the divides between SSIMs.

This paper argues that, in order to achieve these goals, we should refrain from treating taxonomic SSIMs as theoretical camps or representations of actor beliefs. Rather, we should take seriously the remarks made by several authors that taxonomic SSIMs are no more—and no less—than *ideal-types* and *heuristics* (Heinrichs, 2005; Lompe, 2006; Trench, 2008; Kowarsch, 2016, pp. 82–85; Jahn et al., 2022). In their capacity as ideal-types, taxonomic SSIMs are stylized constructions that illustrate how the science–society relation would look like if the assumptions of the SSIMs would manifest themselves in a pronounced or even extreme form (Weber, 1949/1904). In their capacity as heuristics, taxonomic SSIMs are landmarks that help scholars and science–society actors navigate the landscape of possible positions.

Importantly, the ideal-typical and heuristic interpretation is only applicable to taxonomic SSIMs. The set of non-taxonomic SSIMs, on the other hand, should do justice to the large spectrum of "non-strawman" assumptions that real-world actors (scientists and non-scientists) actually hold. A core claim of this paper is that *taxonomic SSIMs can be used to describe a conceptual space in which we can identify, compare and critically assess real-world assumptions in a constructive manner*. Taxonomic SSIMs promote such a constructive discussion by providing us with boundary cases. Real-world actors' assumptions may approximate these boundary cases, but will not typically be identical to them. Also, actors' assumptions can, and typically will, be pulled towards different taxonomic SSIMs at the same time. This is because actor assumptions are not monolithic, but complex *semantic webs*, i.e. networks of beliefs that actors hold regarding different aspects of science and society (for an illustration, see Fig. 2).

Application: tentative steps towards a reflexive tool

Six dimensions of the science–society relation. While the previous section proposed a theoretical understanding of SSIMs, the following section discusses its practical application. The section rests on an idea mentioned before: that SSIMs and SSIM taxonomies are valuable not only for scholars who study the science–society relations but also for actors (scientists and non-scientists) who engage in real-world science–society interactions. The section presents a first, preliminary sketch of a reflexive tool that may be used to identify and discuss the underlying assumptions of such interactions. The results may be used to design, e.g., advisory processes or research projects. The section discusses three steps, each of which can be adapted to the specifics of a given science-society interaction: First, the identification of fundamental or "philosophical" questions that are relevant to the interaction at hand (this subsection); second, the construction of taxonomic SSIMs that provide ideal-typical answers to these questions (see the section "A modified version of the TDP taxonomy"); and third, the choice of a method for mapping the actors' assumptions in the resulting conceptual space (see the section "Mapping actor assumptions in the conceptual space: methodological considerations").

Starting with the first step, it is useful to discern those aspects of a science-society interaction that touch upon the nature of scientific inquiry (science-related dimensions) from those aspects that focus on the principles of social order and human behavior (society-related dimensions). On a more concrete level, this paper suggests differentiating between the dimensions of epistemic standards, epistemic scope, epistemic interests, social legitimacy, social rationalities, and social structure. These dimensions provide categories under which a variety of key questions can be subsumed. The key questions are more specific than the six dimensions and may be weighted differently in different contexts. Also, actors may identify questions that are unique to a given interaction. However, starting from the literature[2] we can determine a tentative list of questions that are generally relevant in science-society interactions. The following considerations thus focus on general issues of the science–society relation, acknowledging that the key questions would have to be adapted in a specific context.

As a methodological note, it should be clear that this framework of dimensions and key questions is one of several ways to systematize the diversity of aspects that are relevant to the science-society relation (for alternative systematizations, see e.g. Lincoln and Guba, 2000; Fazey et al., 2018; Skelton, 2021). This follows straightforwardly from the ideal-typical approach discussed above. It should also be clear that systematizations of this sort cannot plausibly claim to be "authoritative" with respect to, e.g., the exact number and naming of dimensions, or the wording of the key questions. For instance, the fact that the following framework features six rather than, say, four or eight dimensions is a pragmatic compromise between complexity reduction and depth of detail. Furthermore, note that the differentiation between science-related and society-related dimensions does not mean that aspects that are part of the former are not social, or that aspects that are part of the latter have nothing to do with science; in fact, the question of whether these aspects can be separated neatly is answered quite differently by the SSIMs discussed in the next subsection. The differentiation should therefore be seen as one possible way of setting up these kinds of questions, not as a statement about the nature of science and society.

The science-related dimensions can be characterized as follows:

(1) The dimension of epistemic standards refers to the norms, procedures, and regulative ideals that constitute "good science". It also includes aspects of scientific quality assurance. Disagreements about the right epistemic standards constitute different views of how research processes should be designed. Key questions in this dimension refer to a range of procedural aspects of science, such as the ideal of value-freedom and its relation to objectivity, the integration of extra-scientific stakeholders into the research process, the role of extra-scientific (e.g. economic) influences on science, or quality-assuring measures such as the peer-review process.

(2) The dimension of epistemic scope covers the epistemological and metaphysical principles of science: its limits, its reliability, its ability to find true and meaningful facts, and its relation to other types of knowledge. Disagreements in this dimension imply different ideas of what we can expect from science (science's "epistemic power"). Related key questions include issues of uncertainty and reliability, the nature of scientific and societal problems, the differences and similarities between scientific and non-scientific (local, traditional, etc.) knowledge, or the question of whether scientific knowledge is socially contingent ("constructed").

(3) The dimension of epistemic interests refers to the research problems that science should address, including the procedures by which research agendas should be determined. Disagreements in this dimension give rise to different views of how to discern the relevant research problems from the "vast oceans of truth that aren't worth exploring" (Kitcher, 2001, p. 148). Key aspects include questions such as whether research agendas should be determined autonomously by scientists, whether "pure" science has more or less value than applied science, whether basic and curiosity-driven research will yield practical applications in the long run, and how society should support the implementation of research agendas with financial and other resources.

The society-related dimensions can be characterized as follows:

(4) The dimension of social legitimacy covers the procedural and substantial properties that constitute "good" decisions in societal contexts (e.g. in policy-making), including the authority that different actors should have in these contexts. Disagreements in this dimension imply diverging views of scientists' roles in public debates and decisions. The dimension includes the general question of what a practical decision needs to count as legitimate, but also more specific questions regarding the societal authority of scientists, the possibility and desirability of political neutrality, or the issue of whom or what scientists can represent in a decision-process.

(5) The dimension of social rationalities addresses the nature of "good" practical reasons and their adoption by societal actors. The focus is on the conditions under which actors will or should act on the basis of scientific results. As evidence-based action presupposes knowledge of the current state of science, this dimension also includes aspects of science communication. Disagreements in this dimension give rise to different views of rational decision-making and the public understanding of science. Crucial questions are how important evidence is for action (compared to, e.g., values), how research results should be communicated, and what role motivated reasoning plays in the acceptance of evidence by societal actors.

(6) The dimension of social structure refers to the fundamental structure of modern societies, with science as one of many elements of that structure. Disagreements in this dimension lead to diverging ideas of how society is to be understood and how different societal spheres such as science, policy, or the general public can interact with each other. Key questions refer to the boundaries between science and society, the role of institutions (e.g. boundary organizations), the structural unity or fragmentation of society, the nature of conflict and power in society, or the possibility of understanding and steering society from a global planner perspective.

A modified version of the TDP taxonomy. The outlined dimensions describe a promising way to identify the fundamental or "philosophical" aspects of science-society interactions. As can be seen from the above list, however, these aspects are numerous, complex, and non-trivial. This is where taxonomic SSIMs come in: by suggesting ideal-typical answers to the above questions, they provide conceptual orientation and help to understand potential disagreements. As discussed before, these answers are not meant to be "true" or "false", but to serve as boundary cases that demarcate a conceptual space. This paper suggests a modified version of the TDP taxonomy for this purpose. As said before, the TDP taxonomy is not the only SSIM scheme on the market. However, while it would in principle be possible to take a different SSIM taxonomy as a starting point, the TDP taxonomy seems to be well suited due to its prominence and its conceptual breadth (particularly in comparison to dualist taxonomies such as the mode 1/2 distinction). Moreover, the TDP taxonomy provides a promising basis to include science–society aspects beyond Habermas' original focus on scientific policy advice. Besides this wider thematic focus, the following modification of the TDP taxonomy includes a more neutral terminology (without negative connotations) in order to ensure an open dialog. As the relevant conceptual space may vary with the specifics of an interaction, these SSIMs may be further modified to address additional questions or philosophical positions. They may also be formulated in a less abstract and more context-specific way. Despite this flexibility, however, the following descriptions may serve as a solid starting point.

(T') The expert-centered SSIM modifies Habermas' technocratic model. In the dimension of epistemic standards, the SSIM holds that science is and should be value-free. This includes the research process itself, but also the determination of research agendas and the preparation of practical applications. Scientific quality is assured by peer review, which reliably filters out subjectivity and extra-scientific (e.g. financial) interests. Societal actors play no role in science. In the dimension of epistemic scope, the SSIM holds that science can solve most societal problems. Uncertainty is, if at all relevant, of transient nature. Science has privileged access to a context-independent truth, other kinds of knowledge are inferior. In the dimension of epistemic interests, the SSIM emphasizes basic research and scientific autonomy. Practical applications are thought to flow naturally from basic research. Society is to provide sufficient financial resources to science. In the dimension of social legitimacy, the SSIM is inspired by Plato's *Republic*, arguing that society is best governed by "lovers of that which is and of truth" (book VI, 501c). The SSIM holds that societal decisions are legitimate if they are objectively correct. As scientists possess knowledge about optimal solutions, they are legitimized to make societal decisions. Science represents both the facts and an unbiased ("objective") view of the common good in these decisions. In the dimension of social rationalities, the SSIM holds that action should be purely evidence-based. Societal actors are deemed ignorant and irrational. However, the SSIM also holds that society can be rationalized through top-down education. In the dimension of social structure, the SSIM pictures society as a complex machine that can be steered by a global planner. The boundaries between science and society are thought to be fixed and clear. Normative conflicts and power struggles are not expected.

(D') The decision-centered SSIM is adapted from Habermas' decisionist model. In the dimension of epistemic standards, the SSIM holds that value-freedom may not always be achieved, but that scientists can and should minimize value-ladenness effectively. Peer review helps to reduce values and extra-scientific (e.g. economic) influences. Societal stakeholders are not included in science. In the dimension of epistemic scope, the SSIM is confident that science can approximate truth, although some residual uncertainties might remain. While science is subject to historical change, it represents the best currently available knowledge. Consequently, science trumps other types of knowledge. However, science has nothing to say regarding normative issues. In the dimension of epistemic interests, the SSIM emphasizes society's freedom to grant or limit research funding without offering any justification. Society decides whether basic or applied research is more valuable. In the dimension of social legitimacy, the SSIM treats actors' autonomy as the highest good: societal actors are to make autonomous decisions, and science is to remain neutral regarding societal goals. In the dimension of social rationalities, the SSIM holds that actors' preferences are irrational, but that science can and should provide objective information about effective ways to realize these preferences. Values and facts are assumed to be clearly distinguishable. However, societal actors are free to ignore scientific facts if they do not suit their values. In the dimension of social structure, the SSIM assumes fixed boundaries between science and society. Yet, society is not seen as a structural unity, but as a multiplicity of "various value spheres [that] stand in irreconcilable conflict with each other" (Weber, 1958/1919, p. 126). Science–society interactions are shaped by power and interests, and an integrated social planner perspective is viewed as impossible.

(P') The stakeholder-centered SSIM modifies Habermas' pragmatist model. In the dimension of epistemic standards, the SSIM holds that value-freedom is both impossible and undesirable. Societal actors are included in all stages of science. Quality assurance is realized through an extended peer review that involves societal stakeholders. In the dimension of epistemic scope, the SSIM argues that science is essentially uncertain, and that societal problems are unfit for engineering solutions ("wicked problems"). All knowledge is contingent and "constructed". Consequently, science is but one of many co-equal forms of knowledge. In the dimension of epistemic interests, the SSIM prioritizes applied research. Curiosity-driven research is strongly limited. Society decides about research funding, with a focus on useful and ethically welcomed research. In the dimension of social legitimacy, the SSIM holds that decisions are legitimate if they are ethical and result from a fair and inclusive deliberation. Scientists participate in these deliberations without any special authority. Political neutrality is assumed to be impossible. Rather, scientists take an advocatory role in societal debates (e.g. for sustainability). In the dimension of social rationalities, the SSIM holds that action-guiding values are inseparable from action-guiding facts. What counts as "rational" is highly contingent. Yet, actors can learn from each other, which also means that scientists and non-scientists should engage in mutual learning processes. In the dimension of social structure, the SSIM holds that society is an uncontrollable, highly heterogeneous multiplicity. Despite this diversity, conflicts can be resolved through respectful deliberation. Boundaries between science and society are assumed to be permeable and subject to change.

An overview of the proposed dimensions and ideal-typical SSIMs is given in Tables 1 and 2.

Mapping actor assumptions in the conceptual space: methodological considerations. In combination, the ideal-typical SSIMs and the thematic dimensions describe a conceptual space, i.e. a system of coordinates that helps to identify, compare and discuss actor assumptions. While the outlined tool has to be further developed and tested, the general idea should be clear from the previous sections: the tool would assess the attitudes that different actors have towards the key questions in each dimension; it would then determine the actors' proximity to the ideal-typical SSIMs, e.g. on a Likert scale (see Fig. 3a–c); finally, the tool would determine convergences and disagreements between actors (see Fig. 3d). This mapping of assumptions in the conceptual space could provide the ground for further discussions among actors and, ideally, help to design science–society interactions.

The practical application of such a tool may be imagined in several ways. Note again that this paper is only a first step, and that the methodological specifics and the empirical testing must be elaborated on in future work. Yet we can point towards some general considerations. For this, it is useful to distinguish between first-person, second-person, and third-person approaches (combinations are possible):

- In a first-person approach, actors may use the tool as a means of self-reflection, as well as a vehicle to make their assumptions explicit for an audience. Individual actors may find this helpful to get a clearer picture of their own background assumptions and to increase their reflexivity (Schwandt, 2011; Berger, 2015; Beck et al., 2021). The tool may also be relevant for collective actors (institutions, organizations, etc.) who wish to inform their stakeholders (clients, partners, or the public) about their science–society assumptions. We could even imagine a standardization of such a self-assessment tool in a given context. If a number of institutions would agree on a specific formulation of the tool in their concrete context, and if each of these institutions would perform the self-assessment and publish the results, stakeholders could compare the SSIMs used by these institutions in a transparent manner. This could be a

Table 1 Generic dimensions and key questions of science-society interactions.

	Dimension	Subject	Key questions	Exemplary references
Science-related dimensions	Epistemic standards	The set of norms, procedures and regulative ideals that constitute "good science".	• Can and should research be value-free? • Should research involve societal stakeholders? • How should scientific quality be assured? • How should extra-scientific (e.g. economic) influences be addressed in science?	Merton (1973), Lacey (1999), Longino (2002), Novotny (2003), Daston and Galison (2007), Carrier et al. (2008), Douglas (2009), Wilholt (2009), Kitcher (2011), Bremer and Meisch (2017).
	Epistemic scope	The epistemological and metaphysical principles of science.	• How certain can scientific claims be? • Can science solve social problems? • Is science superior to other types of knowledge? • Is science universal or historically and socially contingent?	Kuhn (1962), Latour and Woolgar (1979), Rittel and Webber (1973), Funtowicz and Ravetz (1993), Wynne (1996), Sarewitz (2004), Biddle (2013), Foyer and Kervran (2017).
	Epistemic interests	The problems, questions and challenges that science should address.	• Should scientists enjoy freedom of research? • What is the value of applied vs. "pure" science? • How should research resources be allocated? • Will basic research lead to practical applications (in the long run)?	Bush (1995), Polanyi (1962), Habermas (1971), Koertge (2000), Kitcher (2001), Kourany (2003), Wilholt (2010), Sarewitz (2016), Fazey et al. (2018).
Society-related dimensions	Social legitimacy	The procedural and substantial properties that constitute "good" decisions.	• What makes societal decisions legitimate? • Whom/what can scientists represent in society? • What role should scientists play in societal debates? • Does scientific authority imply decision authority in society?	Lackey (2007), Brown (2009), Pielke (2012), Turnhout et al. (2013), Wittmayer and Schäpke (2014), Edenhofer and Kowarsch (2015), Heazle and Kane (2016).
	Social rationalities	The nature of "good" practical reasons and their adoption by societal actors.	• Should practical decisions be evidence-based? • What role do values play in decision-making? • How should research results be communicated? • What role do world views and motivated reasoning play for the acceptance of evidence?	Douglas and Wildavsky (1983), Einsiedel (2000), Black (2001), Oreskes (2004), Sarewitz (2004), Sturgis and Allum (2004), Trench (2008), Kahan et al. (2011), Martin et al. (2020).
	Social structure	The fundamental structural principles of modern societies.	• Are science-society boundaries fix or fluent? • What role can/should boundary organizations play? • How does power shape society–society relations? • Can society be steered by a global planner?	Weber (1919), Luhmann (1995), Weingart (1999), Guston (2001), Miller (2001), Dunlap and Brulle (2015), Grundmann and Rödder (2019).

valuable service to the stakeholders and may spark a fruitful debate in the respective context.

- In a second-person approach, the tool may be used as a means of group reflection, e.g. in a workshop. Such an approach may be sensible in contexts where scientists and non-scientists collaborate over long periods of time (transdisciplinary projects, mixed committees, etc.). Contrary to a first-person approach, where actors merely assess and communicate their assumptions, this approach is more deliberative. Actors would start by collectively interpreting and modifying the key questions and ideal-typical SSIMs in their context. They would then locate themselves in the resulting conceptual space. The main part would consist of deliberation about controversial assumptions. After that, actors may use the tool again to identify possible changes in beliefs. Finally, actors would discuss the practical implications for their collaborative projects. An important source for developing the tool in this direction is the *Toolbox Dialog* approach (Eigenbrode et al., 2007; Hubbs et al., 2021; Laursen et al., 2021), a workshop-based method in which "members of [cross-disciplinary] teams explore the implicit beliefs and values that influence their project contributions" (Hubbs et al., 2021, p. xiii). Evaluations of Toolbox workshops are promising (Rinkus and O'Rourke, 2021; Robinson and Gonnerman, 2021), which justifies hopes that the tool envisioned in this paper may be applicable in a second-person approach. Similarly, there is literature on deliberative citizen panels in the science–society field that offers further methodological inspiration (e.g. Bertrand et al., 2017).
- In a third-person approach, the tool may be used to identify actors' assumptions from an outside perspective. Rather than initiating a deliberation or assessing one's own assumptions, this type of approach focusses on gathering and interpreting data. This may be useful for empirical researchers, but also for institutions or project organizers who seek information about their stakeholders' expectations. These data would reveal how broad the spectrum of assumptions held in a given target group actually is, and may help institutions or organizers to identify trade-offs and synergies in their stakeholder activities. The fact that similar data have been gathered in other studies (Steel et al., 2004; Gray and Campbell, 2009; Reiners et al., 2013; Steel et al., 2017; Van der Hel, 2018) shows that actors are prepared to answer the tool's key questions (in questionnaires, interviews, etc.) despite their abstract and philosophical character. Additionally, the tool may be used to generate empirical hypotheses about actor assumptions. These hypotheses could be tested either directly, i.e. by surveying the respective actors, or indirectly through observation, discourse analysis, or other methods.

Clonclusion and open questions

This paper has discussed the strengths and weaknesses of SSIMs, focusing on the popular distinction between technocratic, decisionist and pragmatist models (the TDP taxonomy). It has argued that SSIMs and SSIM taxonomies are valuable reducers of complexity and illuminators of conceptual divides. However, these merits are undermined by a tendency in the science–society literature to treat taxonomic SSIMs as antagonistic theoretical camps or as representations of actor beliefs. To avoid the "straw man" debates that result from this tendency, the paper has argued that we should put more emphasis on the ideal-typical and heuristic nature of SSIMs. Starting from this interpretation, the

Table 2 Key assumptions of three ideal-typical taxonomic SSIMs (adapted from the TDP taxonomy).

	Dimension	Expert-centered SSIM (T′)	Decision-centered SSIM (D′)	Stakeholder-centered SSIM (P′)
Science-related dimensions	Epistemic standards	• Value-freedom is desirable and possible (incl. agenda-setting and applications). • No involvement of stakeholders. • Quality assurance through standardized peer review. • Extra-scientific influence on science is reliably filtered out.	• Value-freedom is desirable (excl. agenda-setting and applications), but not always possible. • No involvement of stakeholders. • Quality assurance through standardized peer review. • Extra-scientific influences on science can be minimized.	• Value-freedom is undesirable and impossible. • Societal stakeholders included in all stages of science. • Quality assurance through extended peer review. • Extra-scientific influences on science are inevitable.
	Epistemic scope	• Uncertainty is either irrelevant or transient. • Science is able to solve most issues of human life (in the long run). • Science is generally superior to other forms of knowledge. • Science is universally valid.	• Uncertainty can be reduced, although not completely eliminated. • Science is powerful, but limited. • Science is only superior with regard to descriptive problems. • Science is subject to historical change.	• Science is essentially uncertain. • Science cannot solve societal ("wicked") problems. • Science is one of many co-equal forms of knowledge. • Science is socially and historically contingent ("constructed").
	Epistemic interests	• Full freedom of research. • Basic ("pure") science is more valuable than applied science. • Society is to provide financial resources, science is not accountable for their use. • Basic research leads to practical applications (in the long run).	• Limited freedom of research (dependent on societal funding). • Society determines value of basic vs. applied science. • Society grants or limits funding without accountability to science. • Basic research may not always lead to practical applications.	• Low freedom of research (society co-determines agendas). • Applied science is more valuable than basic science. • Focus on useful and ethical science, science is accountable to society. • Basic research not needed for practical applications.
Society-related dimensions	Social legitimacy	• Decisions are legitimate if objectively correct. • Science represents facts and unbiased (objective) common good. • Decision-maker role for science. • Science's epistemic authority implies practical decision authority.	• Decisions are legitimate if agreed by autonomous actors. • Science represents only current knowledge in societal decisions. • Advisory role for scientists. • Science holds epistemic authority, but no practical authority.	• Decisions are legitimate if fair and ethically defensible. • Science (co-)represents ethical concerns (e.g. sustainability). • Activist role for scientists. • No authority for science (neither epistemic, nor practical).
	Social rationalities	• Action is and should be purely evidence-based. • Values are irrelevant for action. • Societal actors are to be educated by science (top-down). • Subjectivity and motivated reasoning are surmountable.	• Action needs evidence and values (can be cleanly separated). • Values are irrational. • Societal actors are free to ignore scientific advice. • Subjectivity can be minimized, but not completely eliminated.	• Action needs evidence and values (cannot be separated). • Values (co-)determine goals and means of action. • Bidirectional learning between science and society • Subjectivity is irreducible.
	Social structure	• Science-society boundaries are clear and fixed. • Society is a complex, but a controllable machine. • Science–society relation is shaped by reason, not power. • Global planner perspective.	• Science-society boundaries are fixed. • Society is a clash of idiosyncratic values and subjective interests. • Science–society relation is shaped by interests and power. • Multiple societal spheres (no integrated perspective).	• Science–society boundaries are ambiguous and fluent. • Society is cultural diversity. • Science–society relations are shaped by debate and deliberation. • Multiple societal spheres (integration through deliberation).

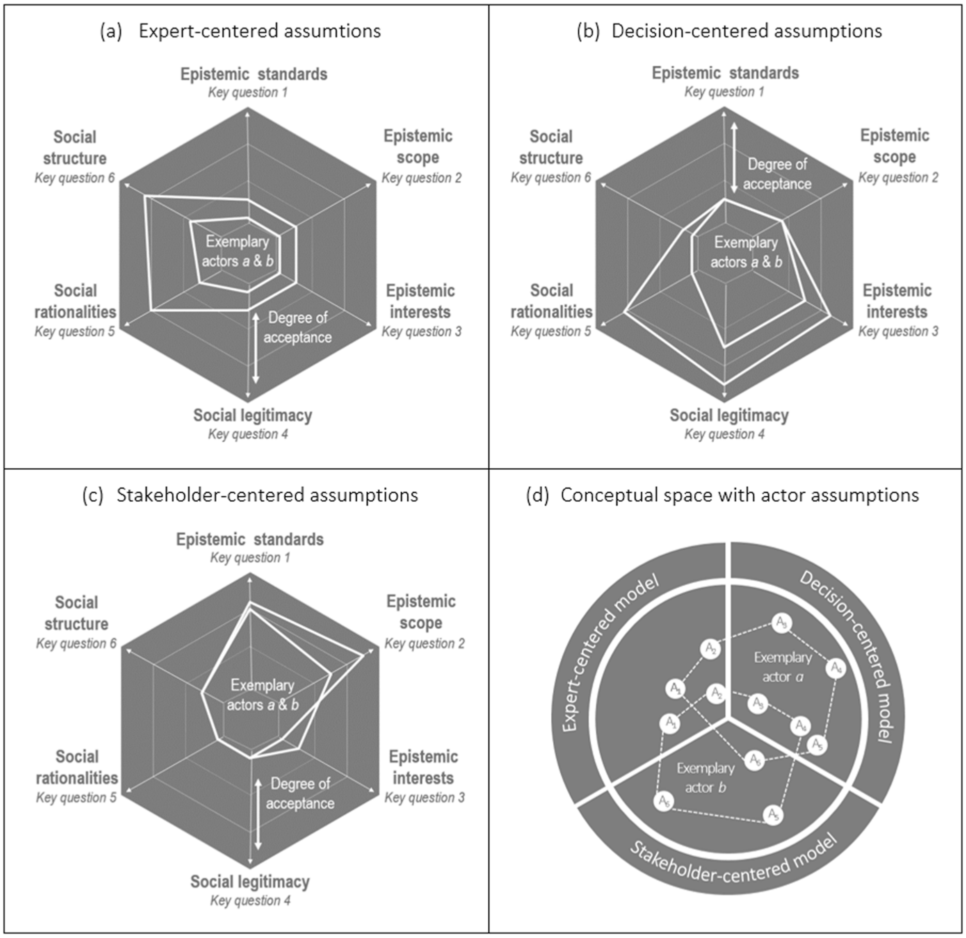

Fig. 3 Mapping of actor assumptions in the conceptual space. Assumptions are identified by determining the actors' acceptance of each taxonomic SSIM in each thematic dimension, e.g. on a Likert scale (**a**–**c**). Convergences and differences between actors are assessed by comparing the position of the actors' non-taxonomic SSIMs in the conceptual space.

paper has presented some tentative ideas for a reflexive tool. This tool consists of six dimensions of key questions and a modified version of the TDP taxonomy. It uses the TDP models as boundary cases that demarcate a conceptual space. By locating themselves in this conceptual space, actors (scientists and non-scientists) can identify, compare and discuss their implicit assumptions. The results may be used to improve science-society interactions in diverse contexts, e.g. in advisory processes or stakeholder encounters within research projects.

It may be objected that that the envisioned tool is too abstract to address real-world science–society interactions. However, this paper has not claimed that the tool can be readily applied. It should rather be seen as a starting point from which more context-specific versions can be developed. Another objection may be that actor assumptions can be identified without taxonomic SSIMs, just using the key questions. Note, however, that this paper has not described taxonomic SSIMs as *necessary*, but as *beneficial*. Actors may find it easier to unwrap their own assumptions if they can indicate the degree to which they accept or reject a clear-cut narrative. By locating their assumptions in a common conceptual space, taxonomic SSIMs may also help actors understand the extent and gravity of potential disagreements. A third, connected objection is that the tool does not show how such disagreements can be resolved (see e.g. Failing et al., 2007; Laursen et al., 2021). This point is well taken. However, transparency about fundamental assumptions is a promising starting ground, and may even be regarded as a value in itself (Elliott and McKaughan, 2014; Elliott and Resnik, 2014). Thus, while the issue of potential disagreements is indeed crucial, it does not speak against the tool.

Regarding the theoretical part of this paper, there are two obvious, yet opposing objections: some may argue that taxonomic SSIMs are more than ideal-types, namely actual bearers of truth and falsity; others may argue that, quite on the contrary, taxonomic SSIMs have always been regarded as ideal-types, which makes the ideal-typical interpretation somewhat trivial. While this paper disagrees with both objections, they point towards a crucial ambivalence in the science–society literature. It is true that taxonomic SSIMs have often been described as ideal-types (Heinrichs, 2005; Lompe, 2006; Wittmayer and Schäpke, 2014; Kowarsch, 2016; Jahn et al., 2022). As argued before, however, this point has not been systematically elaborated in the science–society literature so far. Also, the point is counteracted by the discussed tendencies in the science–society literature, such as the popular idea that certain actors are "clearly" (Beck, 2011, p. 298) guilty of using a false taxonomic SSIM. The insight that SSIMs should not be seen as antagonistic theory camps is also counteracted by polemics against certain taxonomic SSIMs, as well as the widespread discomfort that these taxonomic SSIMs are "refusing to die despite so many mortal blows" (Durant, 2016, p. 31, see also Pielke, 2012, p. 8; Van der Hel, 2018, p. 256). Finally, if the ideal-typical interpretation were trivial, worries that taxonomic SSIMs are "straw-man" would be unnecessary. Still several authors voiced exactly this worry (Sturgis and Allum, 2004; Trench, 2008; Martin, 2012).

This motivates the conjecture that, rather than being regarded as ideal-types, taxonomic SSIMs are in fact often seen as antagonistic theory camps and as representations of actor beliefs in the science–society literature. This paper has argued that this is an unproductive perspective. Note, however, that this paper has not claimed that all SSIMs are equally convincing, philosophically speaking, but that this may not be a *fruitful question*—at least not if the aim is to provide conceptual orientation and to enable an open discussion among the participants of a science-society interaction. This paper should therefore not be taken to defend some sort of SSIM relativism; rather, the idea is that taxonomic SSIMs, together with the six dimensions of key questions, provide us with a way in which actor assumptions can be identified and then, in a subsequent debate, be constructively discussed among actors. Furthermore, the paper has not argued that it is strictly *impossible* for an actor to subscribe to all assumptions of a taxonomic SSIM in their purest form. The point is rather that this is not typical, and that we should not focus on such extreme cases. As a final remark, note that the theoretical and practical claims of this paper are to some degree independent: even if one insists that a taxonomic SSIM is plain false, one can still use this SSIM as a heuristics to identify actor assumptions. Vice versa, even if one believes that the envisioned tool is unfit for real-world application, the theoretical considerations may still enrich one's understanding of SSIMs and the science–society relation.

Endnotes.

1. Several authors have proposed modifications of the classic TDP taxonomy, leading to a greater (see e.g. Millstone, 2005; Kowarsch, 2016) or a smaller number of taxonomy members (e.g. when technocratic and decisionist models are subsumed under the linear model, see Weingart, 1999; Lompe, 2006; Durant, 2016). A variation of the decisionist model was already discussed in Habermas (1970). But contrary to the classic version of the TDP taxonomy, these modifications have either not been widely adopted, or are not used in a consistent sense throughout the literature.
2. Most sources used in this paper come from science and technology studies, philosophy of science, and the transdisciplinarity/co-creation literature (see Table 2). Note that a so-called "systematic" literature review may not be more authoritative, as the relevant terminologies are too heterogeneous to define sufficiently inclusive sets of keywords.

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