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'Wicked' Philosophy – Philosophy of Science for Interdisciplinary Studies into Complex Problems

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ABSTRACT

To confront complex, 'wicked' problems such as climate change and migration, science is essential. But what type of knowledge can science provide and what do we actually need? What is the role of the philosophy of science in clarifying what knowledge is required and how to bring it together? To address these pivotal questions, this article reviews three scientific approaches: the empirical cycle (the logical empiricist model reigning in the natural sciences), the hermeneutic cycle (the interpretive model mainly used in the social sciences and humanities), and the model cycle (a more recently emerging approach). Each has its strengths and limitations in dealing with complex problems. We discuss opportunities to combine the various approaches to gain the most from them and provide illustrative examples of how students can be encouraged to understand and integrate the different perspectives they contain. To enhance this, we propose a 'wicked' philosophy of science that takes complexity thinking as an overarching framework; as it enables us to combine realist and constructionist perspectives, it offers a more nuanced approach to knowledge acquisition. Given the post-truth society we live in, the proposed 'wicked' philosophy also advocates a broader rationality concept that includes emotive and value-laden aspects, and a reflexive science that continually assesses its impacts. The ultimate aim is to equip students with critical, reflexive, and integrative thinking skills that help prepare them for interdisciplinary research on complex problems, thus cultivating a scientific approach that contributes to finding solutions to the pressing challenges we are currently facing.

Keywords: Complex Problems; Philosophy of Science; Interdisciplinarity; Sustainability Challenges; Challenge Based Learning; Complexity Thinking; Reflexivity

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1. Introduction

Traditionally, science has aimed to provide answers to questions relating to the world in which we live. Can modern science now also help us find answers to the highly complex problems we are currently confronted with? Can it offer explanations and help find sustainable solutions to the issues that we are facing? If so, what then is the role and the value of natural sciences, and what is the role of the social sciences and the humanities? How can we combine and integrate knowledge gained in diverse disciplines to provide insights, explanations and solutions? And what is the role of the philosophy of science in this process? These are leading questions within any program that takes as its point of departure today's urgent problems, as is the case within the Bachelor Future Planet Studies offered by the Institute for Interdisciplinary Studies and the Bachelor Interdisciplinary Social Science offered by the Faculty of Social Sciences of the University of Amsterdam.

Future Planet Studies focus on the complex sustainable issues that characterize this day and age, in which human interventions appear to have such profound effects on the environment that theorists have introduced the term Anthropocene to designate the decisive impact [1,2]. Worldwide, there is a call to take an interdisciplinary perspective on the so-called 'grand challenges' such as climate change, energy, food and water demand – issued by various scientific forums such as the National Academy of Sciences, the Stockholm Resilience Centre, the International Science Cooperation to Meet Global 'Grand Challenges,' and the Platform Future Earth [3–6]. In answer to this call, Future Planet Studies cover a broad range of disciplines from the whole scientific gamut. The curriculum incorporates earth science, ecology, chemistry, human geography, political science, spatial planning and economics. For only by taking an interdisciplinary approach and combining knowledge from both the natural and the social sciences can we hope to address the complex problems and develop solutions to ensure a sustainable future for humankind on our planet [7].

In the same vein, the Bachelor Interdisciplinary Social Science incorporates a wide range of disciplines to cover equally complex problems in the social domain, such as urbanization, global health, and migration. The disciplines incorporated in this program are all related to the social sciences but nevertheless still include a broad variety, ranging from psychology, sociology and anthropology to human geography and urban planning.

In both programs, the philosophy of science course fulfills an important function in putting the role of the various disciplines into perspective and in building bridges between the different approaches. Before highlighting what exactly is the role of the varying approaches with regard to the complex problems that are at the central focus in our interdisciplinary programs (section 3), we will first examine the peculiar nature of complex problems and discuss the calls for an appropriate approach to address these issues (section 2). After that, the possibilities for integrating the various perspectives in an overarching complexity framework are sketched (paragraph 4). In the next section (section 5), we focus on the role of science and technology in finding solutions for our pressing problems. We round off with a reflection on what education in the philosophy of science is needed to prepare today's students of complex issues adequately for the challenges that lie ahead of them (section 6).

2. Complex Problems and the Call for a Shift towards Complexity Thinking

Climate change, sustainable energy, food and water supply, global health issues, urbanization and migration are characterized by such complexity that they are frequently labeled as 'wicked' problems. It has proven to be very difficult if not to say impossible to reach agreement on the problem definitions, let alone reach consensus about the best way to solve these issues. This lack of agreement on the problem definitions and solutions are two of the main characteristics of 'wicked' problems [8]. They often relate to complex adaptive systems (CAS) such as ecosystems, the climate, economic systems, cities or societies. Complex adaptive systems are networks or collections of mutually connected, interdependent agents capable of learning and adapting to changes in their environment via their capacities for self-organization, resilience and emergence [9]. Hence, 'wicked' problems imply an array of factors and actors, and play at different system levels which are also connected to each other on higher levels, including the global level. In the context of sustainability studies, the so-called food-water-energy nexus, which in turn is intrinsically connected to climate change, is a well-known example [10]. This interconnectivity is another important characteristic of 'wicked' problems [9]. It renders them not merely complicated, but truly complex: they are multi-level phenomena involving a multiplicity of mutually interacting (f)actors, and their functions cannot be localised in any specific component. As a result, we cannot simply combine the various elements of a complex problem to find satisfactory explanations, for the whole is more than the sum of its parts. Because of their inextricable, chaotic and ambiguous nature, uncertainty and unpredictability are accompanying distinguishing features [11]. Moreover, they represent issues that have turned out to be resistant to easy solutions and rather persistent [8].

The advent of complex problems has given rise to a new, concurrent way of thinking: complexity thinking. In the simplest definition, complexity thinking can be described as an approach in which the peculiar characteristics of 'wicked' problems are taken into account. Complexity thinking needs to do justice to the intricate connections, and continuous feedback loops between the phenomena, and deal with the uncertainties and undesired side effects accompanying this process [11, 12]. Reflection on the peculiar character of complex problems makes us sensitive to the fact that they pose today's scientists a different kind of task than they have traditionally been dealing with. Whereas researchers in conventional disciplinary problem fields are often mainly focused on finding explanations and bringing about understanding, the current complex problems such as climate change and water issues have become so pressing that an appeal is made to go beyond explaining and understanding and to come up with useful ideas and robust solutions to help realize change [13].

The main claim of those who call for a shift in our thinking is that currently, the knowledge production process is based on simplification methods that distort our thinking [11, 12]. Differentiation or unification divides elements into established hierarchies or organizes them around a core of principal concepts, but both operations are too simple. The same can be said about the reduction of the biological to the physical and the human to the biological. Such methods of division, reduction and abstraction, which are still often deployed, allow complex phenomena to slip through our fingers. And when we isolate these phenomena from their surroundings, we no longer see the bigger picture.

Some philosophers of science believe that a complexity turn or even a complexity revolution may already be taking place [14,15]. Others argue that such a paradigm shift is vital for scientific development, that we need to shed the one-dimensional perspective dominating our current outlook on reality to proceed to the next stage [11,16–21]. Whatever may be the case, in our program we have taken it upon ourselves to actively explore the potential of this new approach to complex problems. However, that doesn't detract from the importance of taking stock of what traditional scientific approaches are available, what assets they have, and what shortcomings. We therefore start by engaging students in the exploration of the existing approaches in science: the conventional scientific model that is based on the empirical cycle, and the interpretative model that is based on the hermeneutic cycle. But we don't stop there; it is worthwhile to also pay attention to the new evolving approach following the so-called computational or digital turn in (the philosophy of) science, and clarify what functions models and simulations can perform in the context of complex problems. Below it will be shown how we can try to help students gain insight into important core concepts within the philosophy of science while explaining how the various approaches can help us deal with the 'wicked' problems we are currently faced with.

3. The Contribution of Various Scientific Approaches to the Study of Complex Problems

3.1 The 'Standard' Approach: The Empirical Cycle

The empirical cycle can be characterized as a way of doing research specifically focused on finding explanations, for instance by searching for systemic mechanisms or processes underlying certain natural or social phenomena. Based on the pillars of logic and empirical observations (hence the label logical empiricism or positivism), this method takes as its point of departure systematic observations from which theories are induced about the ways of the world, which are then tested and evaluated in controlled experimental settings. It can be regarded as the ground model of modern science and is celebrated for the many insights and explanations it has brought us. Insights that in turn often have led to useful and influential technological innovations.

Under the influence of the well-known philosopher of science Karl Popper [22–25], the empirical cycle gradually evolved into the deductive-nomological model [26], which became the 'standard' model for scientific research. The hope was that by exchanging verification for falsification, a solution could be found for the induction problem, i.e., the fact that we can never infer a general law from a limited set of supporting observations. The idea behind Popper's critical rationalist approach was that we can try to come as close to the truth as possible by repeatedly attempting to falsify theoretical hypotheses; the more we fail in doing so, the more likely the theory is to be true.

Other philosophers of science have made us aware that this method doesn't solve the underlying problem. They point out that falsification is essentially nothing but disproof based on the same type of observations that we rely on when looking for verification [27]. So refutation basically depends for proof on the same method of testing theories against independent facts [28,29]. This idea of independent facts is problematic, as observations are not direct but inevitably theory-laden and dependent on certain paradigms that guide scientists' research [30]. Moreover, it has been shown that it is impossible to test an independent hypothesis, as scientific theories can only be evaluated in relation to the whole interdependent structure that a theory entails [31].

So though Popper hoped to provide us with demarcation criteria that would enable us to distinguish scientific knowledge from bad science or pseudoscience, his critical rationalism did not offer a definite way out of some philosophical issues. We have to make students aware that we must learn to live with the fact that our explanations are fallible and that our knowledge to a certain extent always remains tentative.

3.2. The 'Alternative' Approach: The Hermeneutic Cycle

While it is often presented as the 'standard' model, numerous objections have been raised against the claim that the basic principles of the deductive-nomological model apply universally to all academic studies and scientific research. Especially social scientists protested against the postulate of naturalism, the nomothetic postulate and the postulate of analysability and the accompanying atomist, reductionist approach [11,32] that dominate in the natural sciences. They claim that another, more holistic approach is needed to study social phenomena and complex problems.

The interpretative model has been pushed forward as an answer to this need, at least for the study of social phenomena. In this approach, the focus shifts from finding explanations to gaining a better understanding of the behavior of people and the world we live in. Practitioners within this approach are particularly attentive to the way in which experienced subjects construe their world. They acknowledge that all manners to frame, interpret and understand the world, including knowledge of that which we have come to regard as 'nature', are human constructions [33,34]. Constructions that are influenced by the conceptual schemes that we hold and embedded in social interaction by way of language.

At the heart of the interpretative approach lies the 'method' of *Verstehen* [35], which is actually not so much a scientific technique but should rather be seen as an ontological process, since interpretation forms the base for our very existence. If we weren't able to grasp what social actors mean, need and want, and wouldn't be able to reconstruct how human beings and non-human beings (inter) act, we would not be able to make sense of the world at all. Reality comes to life through language, through the narratives we tell about ourselves and our experiences in the world, and through the way we discuss and communicate matters of concern. Analysis of the latter, which are referred to as discourses, is a form of research regularly used in the interpretative approach. Particularly postmodernist thinkers attach great importance to discourse analysis. They point out that everyday means of communication allow us to express ourselves and relate our experiences, yet also constrain us within existing power structures, forcing us to adopt certain norms and identities [36–39].

The scientific usefulness of the interpretative model has often been debated. One objection is that it doesn't seem to be able to supply us with much generalizable knowledge, as our theories about the world seem to be based on rather idiosyncratic conceptual schemes. Another objection is that more often than not, interpretative researchers still act as if they are objective know-alls that can unilaterally determine the adequacy of the gained insights. They fail to acknowledge the crucial insight that researchers in the social domain are confronted with a double interpretative challenge, i.e. they always have to interpret a reality that is already interpreted by the ones they research [29]. When they refrain from checking their interpretations of the interpretations of the researched, they end up relying on the very same concept of objectivity as the conventional model. So even though the interpretative model may rest on a deviating ontology and epistemology, the claim that it fundamentally differs from the 'standard' model of knowledge acquisition and can be viewed as an alternative paradigm, can be disputed.

3.3. The 'New' Approach: The Model Cycle

In addition to the critical rationalist and interpretivist approaches in science, in the last decades a new approach has evolved following the so-called computational or digital turn in (the philosophy of) science. It is worthwhile to pay attention to these developments and clarify what functions models and simulations can perform in terms of generating insight into or solutions for our complex problems.

First of all, models and simulations can be used for developing, exploring and applying theories and as tools for scientific experimentation. Making models can be regarded as a kind of thought experiment, a form of simulative model-based reasoning in which mental models of the target system – i.e. the actual system in real life – are manipulated to see if our explanations are correct [40–42]. Researchers can claim their proposed model is reliable by showing that the simulation matches what is known about the actual system – by comparing the results of the model to existing problem analyses, to other experiments, to other simulations or to actual data. The prospect of a new kind of science that enhances the systematic study of possible worlds is highly relevant to the scientific understanding of ecological and social systems [43].

In addition to generating explanations and understanding, simulations can also support us in our efforts to repair or improve these systems. They can serve to test how the solutions that we have thought out for some of our problems may work out in reality. They can help us examine how interventions in a system might change certain properties and with that transform the existing situation. Moreover, they can be used to explore broader implications of our theories in real-life situations [44], for instance whether an intervention will lead to unforeseen side effects.

Furthermore, models and simulations can perform an important role in exploring what might happen and how the future might develop. When used in the form of projections, they can form a springboard for envisioning potential and even physically impossible worlds [45]. This is exactly what simulations are meant to do; they provide a way to visualize virtual realities and potential futures. This is particularly interesting in the context of Future Planet Studies where – as the name reveals – the main concern is how our future may develop. Simulations can be used in science-based visions and scenario development, which can help steer society in the direction of a sustainable future.

However, we should not turn a blind eye to the possible dangers of the new approach. Some fear that the new computational methods are nothing but old wine (the atomistic and reductionist thinking that characterizes the traditional approach) in new bottles (the same kind of mechanical thinking but now formulated in computer language). If that is the case, it may very well be that they'll be just another form of disciplinary imperialism forcing the social sciences and to some extent even the humanities into the realm of the natural sciences, just as the 'standard' scientific model did before.

4. Building Bridges between the Various Approaches

In the foregoing section, we have tried to show how we can help students gain insight into some of the most important core concepts within the philosophy of science, while we examine the available approaches developed in the natural sciences, and in the social sciences and humanities. We also highlighted the assets of each approach in relation to addressing complex problems. As is often the case, these strengths are not without possible shortcomings. Therefore, we think it is important to try and find ways to build bridges between the various approaches.

One way to do this is to engage students in a perspective-taking exercise where we make them sensitive to the differences in emphasis in research from different perspectives. We challenge them to give a description of a concept, first from a realist and then from a constructionist point of view. By analysing important aspects of the definitions, we can gain insight into what distinguishes the two: while the first approach is specifically aimed at studying systems and their underlying structures, the other is more geared to the study of agency. Once that is clarified, we can create more awareness about the implications of the various approaches for the solutions that we come up with for the challenges at hand.

Below we give two examples of such a perspective-taking exercise, one using a concept that is often used in the social sciences and humanities, and another using a concept from the domain of the natural sciences.

4.1. First Example: Building Bridges between Various Conceptions of 'Organization'

As a first example, let's take a look at the concept of 'organization'. We ask our students to read an excerpt from *Social Research Methods*, where it is described how various types of scientists are observed to write in quite different ways about research on how organizations function [46]. We then ask the students to give a description of the concept of 'organization' from a realist point of view and subsequently from a constructionist point of view.① In the realist view, an organization is a tangible object, with standard rules and procedures. As such, it has an objective, external reality that exists apart from the individuals who make up the organization. It constitutes a limiting force that determines the actions of individuals. In the constructionist view, an organization is a unity of goal-directed activities by the people who work in it. An organization is not taken to exist apart from the individuals who constitute the organization; they are the ones who continuously reinforce the rules and procedures or negotiate new ones. The exercise enables us to gain insight into how specific perspectives and definitions can guide, but also limit our view in research. It clarifies that the first definition of an organization matches with a systems perspective, while the latter is more in line with an action-oriented perspective.

The exercise can also help to illuminate how the perspectives that we take, and usually take for granted, determine what we view as adequate interventions or solutions for problems related to the phenomenon under study (e.g., the concept of 'organization' plays an important role in urbanization and realizing sustainable cities). After they have drawn up two different definitions and reflected upon these descriptions, we ask students to imagine they are scientists who have been asked to do research on how we can make a particular organization – in our case, the university – more sustainable. Taking the two definitions as points of departure, they have to name two matching interventions that could make the organization 'university' more sustainable. One intervention needs to fit with a systems description / perspective / approach; the other intervention with an action-oriented description / perspective / approach. The first definition is likely to induce interventions that relate to the physical characteristics of the university (e.g., reduction of energy use by better insulation of the buildings) or structural properties (e.g., the extent to which research groups depend for their funding on the fossil fuel industry or other non-sustainable partners). Taking as a starting point the second definition will probably lead to interventions related to the actions of the people who make up the university (e.g., teachers and students choosing more plant-based lunches, or researchers from various disciplines taking the initiative to start interdisciplinary collaboration projects to address complex sustainability issues).

Doing this exercise can improve students' understanding of what an organization such as the university is. On the one hand, it is a social order that is continuously (re)

① Bryman compares objectivism with constructionism, but we reserve the label objectivism for the epistemological position that is related to a realist ontology. Let it also be said that it would historically be incorrect to claim that all adherents of the 'standard' model are realists and objectivists. Many of them take an agnostic attitude and take an instrumentalist stance, i.e. adhere to the idea that we can at most see our scientific theories as instruments for making predictions, rather than as providing explanations about the structure of reality (which is the claim a realist would make). In the instrumentalist view, scientific theories and the resulting knowledge are seen as equivalent to the instruments used to test acquired knowledge (see references [23,47]). For simplicity's sake, in the context of our bachelor programs, we compare realism with constructionism (or constructivism), and objectivism with perspectivism and relativism, as these are more diametrically opposed positions.

negotiated in daily practice by the individuals that work there (constructionist / perspectivist vision implied in the interpretivist model, action-oriented perspective). At the same time, it is such an embedded and institutionalized set of rules, procedures, and hierarchies that it at least to some extent also has an objective, external reality independent of those individuals and as such cannot be changed at will (realist / objectivist vision inherent in the critical rationalist model, systems perspective). We hope to be able to show students that both perspectives are valuable, and that it will in part depend on the purpose of a particular research which perspective seems most appropriate. But it is important to realize that both perspectives present a limited view of reality. By showing how social actors with their actions continuously produce and reproduce social structures, we enhance students' awareness that structures and actions are not opposites but actually two sides of the same phenomenon [29]. This way, we can try to stretch their minds to think beyond this type of dualistic thinking and reason more in 'both / and' terms instead of in 'either / or' terms. By viewing organizations such as the university as both a stable, highly structured entity and the result of continuously (re)negotiated practices, they can come up with a more comprehensive definition and potentially develop a larger, richer variety of interventions to make universities (and perhaps, later in life, complete cities) more sustainable.

4.2. Second Example: Building Bridges between Various Conceptions of 'Soils'

To emphasize that how you define concepts is an important issue in the natural sciences just as well as in the social sciences and the humanities, we present our Future Planet students with Puig de la Bellacasa's critical analysis of various conceptions of 'soil', which plays a crucial role in sustainable food production, amongst others [48]. In the analysis, it is explained that in the conventional conception, a utilitarian vision of crops as commodifiable produce reigns, and that in this context soils are predominantly viewed as receptacles for crops. Over and against that is put an ecosystem-services approach, which emphasizes the worth of soils beyond their purely economic and monetary value. This clarifies that what 'soil' means in conventional soil science is quite different from how it is conceived in permaculture circles. In the conventional conception, care for soils has an instrumental and exploitative character: the focus is on remediation of worn-out soils, and on soil engineering technologies including artificial fertilizers and enhanced crops (such as Genetically Modified Organisms) that will work around soil's impoverishment and exhaustion. In an ecosystem-services approach, it is emphasized that we need to care for our soils, which leads to a re-evaluation of tillage, fertilizers and other technologies, as well as to a reappraisal of the complex diversity of soil renewal processes that tend to be ignored in our continuous efforts to increase our yields.

Thus, the difference between the two conceptions and accompanying approaches and the consequences of different ontological and epistemological principles in soil science becomes clear. This is exemplified in the tension between the demands for increased production and sustainability; between the accelerated technological solutions that are required if we take the need for intensified production as a central point of departure and the need to acknowledge soil as a slowly renewable entity if we take into consideration the carrying capacity of the earth. What stance we take has huge consequences, not just for how we conceive the concept of 'soil', but also very practically how we care for our earth and how we work the ground.

Puig de la Bellacasa emphasizes that even in the ecosystem-services approach, the conception of soil is still viewed from an anthropocentric perspective: it is all about the functions or services it provides for our human well-being. She proposes to take as an alternative conception: soil as an environment for living organisms and nonliving components, as a living community where these are all mutually interdependent. Hence, the actors in this system need to take good care of the soil. Approaching soil as an environment for organisms emphasizes the interdependent human–soil relations that are at play. It forces us to look not only at how soils produce output and provide services to us, humans, but also at how we are providing for the soil community in order to maintain, repair and take care of this living web. And it encourages us to pay attention to the practical, affective and ethico-political dimensions of soil care (for instance: who provides the ecosystem 'service' and for whom?), inside as well as outside academia. Here too, we hope that the analysis of a concept, in this case the natural scientific concept 'soil', can help students to come up with a more comprehensive definition and potentially develop a larger, richer variety of interventions to make agriculture more sustainable.

4.3. An Overarching Framework Suitable to Address Complex Problems

The elaboration of the existing approaches may have served to show that neither the idea that the scientific endeavor is nothing but objective knowledge production nor the stance that it is nothing but subjective knowledge construction is a tenable position. At the same time, we cannot deny the practical value of an epistemology in which the validity of knowledge claims is defined by some kind of correspondence between our claims about or models of reality and reality itself. Think, for instance, of the value of climate models as forms of representations of reality; if we didn't assume a correspondence between those models and reality, we would not view this as a valuable form of knowledge. Neither can we ignore the fact that the perceived truth of knowledge depends to a large extent on the degree to which statements about reality form a collective, consistent, coherent whole. For if it wasn't for the coherent story that can be told about the human-induced climate change that has set in since the industrial revolution, the whole idea of global warming and the call for action to do something about it would have never resonated.

In the context of studies into complex problems, the comparison of the differing viewpoints on how knowledge is produced leads us back to complexity thinking, the new approach that developed in response to the intricate challenges we encounter [9–14]. The big question is whether complexity thinking can offer a meta-position, an overarching framework in which the various scientific approaches can be brought together and fruitfully used in our search for appropriate solutions. In an effort to realize this, we follow Morin [11] who urges us to abandon the one-dimensional paradigm in which distinction goes hand in hand with reduction, and replace it with a paradigm in which distinction is followed by conjunction or unification. Using complexity thinking as an overarching framework leads us to a critical realist take on reality (see **Table 1**), in which it is acknowledged that we have ample reason to believe that there is an independent reality 'out there', but that we cannot determine exactly which part of reality is objectively real and which part is constructed [49]. ② And it leads us to a fallibilist view with regard to the way we can acquire knowledge. While we are willing to acknowledge that we can never obtain completely objective and certain knowledge as our knowledge of reality is determined by the different conceptual schemes that we use, this doesn't need to stop us from trying to compare those in order to attain valid knowledge.

We propose to combine the correspondence and coherence theory of knowledge to determine what can count as a reliable explanatory theory and what interventions can be considered to be adequate to address the issue. This will not merely be a matter of objectively determining what is the matter (it is clear that to those who do not believe the story about climate change, the facts don't matter), but rather of intersubjectively and critically assessing what is the situation at hand, and what solutions may be feasible and effective. We can use climate models to keep track of the developments in the weather patterns and make projections into the future, but we also need consensus about whether we can indeed speak of climate change and if so, whether it is human induced, and whether we consequently need to take action to alter the course of our climate and if so, which strategies should be pursued. By combining the correspondence and the coherence theory of knowledge, we can come to an epistemology that does justice to the fact that all knowledge acquisition is inevitably guided by the perspective we take, without having to fall into the trap of extreme relativism [50].

The framework of complexity thinking offers the possibility to combine systems thinking and research into physical and social structures with inquiry into agency, thus taking the interrelation between structure and action explicitly into account. This way, by distinguishing without permanently separating the constituent parts, and by connecting elements without creating an oversimplified, unidirectional hierarchy and without reducing the parts to simpler entities, we can develop a new complexity paradigm. While it would be too bold to claim – at least for now – that this leads us to a fully elaborated new philosophy of science tailored to the study of complex problems,

② Whether models and simulations are to be situated in the first column or rather in the third, depends on whether they are regarded a representations of the new complexity approach or merely as additions to the conventional scientific model.

we do try to contribute to this endeavor by bringing together the best features of the different types of ontology and epistemology and different takes on truth and validity, while avoiding the disadvantages. Thus we hope to support the development of an integrated approach that can accommodate the particular character of complex problems, and can help us deal with the urgent and persistent complex problems that threaten our very future.

Table 1. Complexity thinking as a potentially integrative meta-position.

Paradigm / Approach	Critical Rationalism	Interpretivism	Complexity Thinking
Dominant perspective	Systems perspective	Actor's perspective	Dual perspective
Vision on reality (Ontology)	Empirical Realism There is an independent reality 'out there' which we can access immediately.	Constructionism Reality does not exist independent of us; it is at least partly a construct of the human mind.	Critical Realism We have ample reason to believe that there is an independent reality 'out there'. But which part of reality is objectively real and which part is constructed can never be determined exactly. Unmediated access to that independent reality is impossible.
Theory on how we can get to know reality (Epistemology)	Objectivism We can obtain objective knowledge of reality through logical reasoning & empirical research.	Perspectivism + Relativism Our knowledge of reality is based on different and mostly incomparable conceptual schemes.	Perspectivism + Fallibilism Our knowledge of reality is determined by the different conceptual schemes that we use. By comparing them we can try to obtain pretty, though never 100% objective, certain knowledge.
Definition of truth	Truth is defined by correspondence or isomorphy / similarity between claims about or models of reality and reality itself → 'objectivity'.	At most, truth can be defined as coherence within meaning frameworks, in overarching systems of knowledge claims about reality further → 'subjectivity'.	From truth as representation to 'truth' = what works via a network model of correspondence and coherence plus pragmatic criteria on the basis of critical subjectivity.
Quality criteria	Objectivity on the basis of claimed neutrality and value freedom with regard to the research object.	Immersion in the social world produces knowledge that might be subjective but nevertheless hopefully objective valid truth claims.	Objectivity on the basis of critical intersubjectivity and accountability with regard to held assumptions and own position.

Source: cf. Tromp [51].

5. Philosophy of Science in a Post-Truth Society

In sections 3 and 4, a description has been given of what could be regarded as 'the basics' of an interdisciplinary philosophy of science. In more elaborate courses, there may also be room to devote attention to the role of science in society. Such is the case within the Bachelor Interdisciplinary Social Science, where the philosophy of science course is combined with Science & Technology Studies into a 'Philosophy of Boundary Crossing Science' course. That gives us the chance to examine to what extent modern science has managed to fulfill its promises, what merits it has brought us, but also what undesired side-effects it has brought along.

We have come to regard modern science as a systematic learning process through which we try to find rational explanations and solutions for our complex problems. But it can be questioned, as many postmodernists and philosophers of science have done, whether science always produces the most rational solutions. It is clear that science has more than once produced knowledge and technologies that led to less than optimal institutional arrangements and systems. Ironically, the scientific and technological systems which are supposed to solve our problems often generate ever-increasingly complex issues themselves. Some, if not most of the 'wicked' problems we face are essentially unintended, unwanted side effects of well-meant scientific solutions. Limiting the initially much broader concept of rationality to a very restricted technocratic, cognitive-instrumental conception that mainly focuses on controllability and manageability, does not necessarily lead to progress [52–54]. So we must conclude that rational decisions do not by definition coincide with wise decisions.

An additional difficulty is that nowadays, we seem to live in a post-truth society in which the validity of knowledge claims is no longer seen as the result of established facts but more as a matter of personal opinions and convictions [55–57]. It goes to show that postmodernism and constructionism, whatever their assets, can have a destructive effect on the value attached to science when taken to its extreme.

So it could be said that the image and status of science is changing and in need of change. On the one hand, scientists have to raise awareness and understanding amongst the people (including politicians) that they are not know-alls and that they have to deal with a lot of unknowns and uncertainties. On the other hand, they also have to fight a battle against fundamental skeptics and conspiracy thinkers and claim validity with regard to knowledge that to a significant degree is considered factual and true by a large majority of scientific experts. Hopefully, a network theory of knowledge in which both correspondence and coherence elements are incorporated can help to stay out of the potentially disastrous trap of extreme relativism.

Another important step to take is to reintroduce the broader, more encompassing rationality concept [52–54]. First of all, we need a broader rationality concept to better reflect the actual working of the rational being and to offer room to the more emotive and value-laden aspects that evidently also play a role in our assessment of what is true and what is not [58]. An equally important reason is that a broader rationality concept is essential to enhance a more reflexive science, that is a science that has turned itself into a learning organization which is transparent about the position and assumptions it holds. An organization also that is constantly monitoring what potentially causes a discrepancy between its aims and ideals and the actual effects, and does all it can do to reduce the risk of creating precarious situations in the future [59,60]. To encourage this and to make sure they incorporate this attitude early on in their career, students of the Bachelor Interdisciplinary Social Science are required to use what they learned during the 'Philosophy of Boundary Crossing Science' course in their final thesis. It doesn't suffice to merely explain what methodology they want to use to address the chosen research questions; they have to explicitly indicate what position they take as researchers and what assumptions this position rests on, and subsequently reflect on the implications thereof.

6. Conclusions

By analyzing the assumptions underlying the core principles of various research approaches and clarifying what objections and shortcomings have been brought to the table by philosophers of science, students develop a more sophisticated view of what scientific knowledge entails. Particularly in view of the inter- and transdisciplinary research collaborations they are bound to engage in if they are to help solve the complex problems facing us, it is important that they will be able to distinguish various possible ontological and epistemological assumptions and perspectives. But it would be a shame if it would stop there, if we would leave students confused and dazed by the various apparently diametrically opposed approaches. Therefore, it is important that we try to take it a step further and search for ways to combine and integrate the knowledge gained in diverse scientific domains to provide the necessary insights, explanations and solutions for the complex problems at hand. The attempt to develop an interdisciplinary philosophy of science and an overarching framework for complexity thinking as described here can be viewed as our effort to contribute to this endeavor.

While actively engaging with the models of knowledge acquisition described above and doing exercises related to some of the philosophical challenges related to them, we address the types of knowledge and competencies that are needed to help students deal with complex problems in general, and sustainability issues in particular: systems and complexity thinking, perspective-taking, critical and reflexive thinking, anticipatory and futures thinking, interdisciplinary and integrative thinking [61,62]. It is the kind of skills they need when, in their professional lives, they participate in inter- or transdisciplinary research and co-creation processes aimed at finding robust knowledge and solutions for the complex problems that heavily impact our societies.

As regards the question of whether complexity thinking can offer us the desired overarching framework and perhaps even a complete new paradigm to serve a science of the future, the jury is still out. Some fear that it is nothing but a new hype, in which existing terminology is merely replaced by new, complicated and confusing terms. And it still remains to be seen whether it can incorporate the power and agency dimensions that so often have remained out of sight in other scientific approaches. Whatever the developments may be, we can only hope that we will be able to come up with a scientific approach that contributes to a future that can be called 'wicked' in the positive, not in the negative sense of the word.

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