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The Integrative Expert: Moral, Epistemic, and Poietic Virtues in Transformation Research

Michael Poznic [1,*] and Erik Fisher [2]

1 Karlsruhe Institute of Technology, Institute for Technology Assessment and Systems Analysis (ITAS), Karlstraße 11, D-76133 Karlsruhe, Germany
2 School for the Future of Innovation in Society, College of Global Futures, Arizona State University, Tempe, AZ 87587, USA; efisher1@asu.edu
* Correspondence: michael.poznic@kit.edu

Abstract: Over the past 50 years, policy makers have sought to shape new and emerging technologies in light of societal risks, public values, and ethical concerns. While much of this work has taken place during "upstream" research prioritization and "downstream" technology regulation, the actual "midstream" work of engineers and other technical experts has increasingly been seen as a site for governing technology in society. This trend towards "socio-technical integration" is reflected in various governance frameworks such as Sustainable Development (SD), Technology Assessment (TA), and Responsible Innovation (RI) that are at the center of transformation research. Discussions around SD, TA, and RI often focus on meso- and macro-level processes and dynamics, with less attention paid to the qualities of individuals that are needed to support transformation processes. We seek to highlight the importance of micro-level practices by drawing attention to the virtues of technical experts. Drawing on empirical study results from embedding philosophical-reflective dialogues within science and engineering laboratories, we claim that poietic, as well as moral and epistemic, virtues belong to those required of technical experts who foster integrative practices in transformation research.

Keywords: virtues; transformation research; socio-technical integration; responsible innovation; engineering practice; interdisciplinary collaboration

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1. Introduction

Over the past 50 years, new developments in science and technology have increasingly been recognized by the public and policy makers as entailing risks, uncertainties, and concerns. Policy makers have sought to shape new and emerging technologies in light of such considerations. While much of this work has taken place during "upstream" research prioritization and "downstream" technology regulation, the actual "midstream" work of engineers and other technical experts is increasingly seen as a site for governing technology in society. Accordingly, policy makers have called for an integrated approach that addresses these considerations [1,2]. Attention to this "socio-technical integration" [3] is also diversely expressed in governance frameworks such as Sustainable Development (SD), Technology Assessment (TA), and Responsible Innovation (RI), all of which aim for societal transformations and offer methodological approaches that support such changes. However, the exact way in which so-called transformation research should be conducted is a matter of debate. While some emphasize the need for macro- and meso-level changes, others focus on the micro-level of technical practices. We propose that multiple levels of transformation are needed and that a common feature in these debates is the demand identified by Carl Mitcham of *plus respicere* [4], i.e., to "take more into account" on the part of the technical experts who must eventually change their practices as SD, TA, RI and similar governance frameworks become more widely adopted. This demand of *plus respicere* is visible in the development of TA from primarily a parliamentary function to one that now engages a three-fold constellation of policy makers, members of the public and technical experts [5]. It can also be seen in recent demands for "responsible" developments of technological innovation and the attendant rise of RI [6]. Yet, while scholars and practitioners have developed numerous collaborative approaches to support the integration of social and technical considerations during technology development (e.g., [3]) and to support the goals of the governance frameworks in an integrative fashion. While notable scholarly attention is devoted to understanding the role that social scientists and philosophers play in facilitating such collaborations [7–9], far less attention is paid to understanding the role of technical expertise as a practice in contributing to these goals. More specifically, understanding the aspects of engineering and related practices that are helpful or necessary to ensure such integration is a topic that deserves more attention. Such an understanding is critical for effectively designing, conducting and assessing research programs and technology projects that are motivated by the aforementioned governance frameworks and include related integrative components.

In this paper, we build upon philosophy (e.g., [10–20]) and responsible innovation scholarship (e.g., [21–23]), and take the language of virtues as a means to spell out the normative aspects of integrated practices of technical experts, showing how this language applies to integrative efforts in SD, TA, and RI. We conduct a theoretical exposition of the capacities that are found to be exercised by scientists and engineers who participated in prior empirical studies. Using three subfields of philosophy, we identify three individual virtues thought to be consistently present during successful modulations of research and innovation pathways. Additionally, we argue that each of these three individual virtues belongs to a separate class of virtues. We thus seek to contribute both to the philosophical fields of virtue ethics, virtue epistemology, and the philosophy of technology, as well as to the practical design and assessment of projects and programs intended to bring about transformation research, which require the (virtuous) participation of scientists and engineers. Thereby, we argue that such virtue-ethical approaches need to encompass a broader range of virtue types than is usually included. Importantly, the virtues are necessary but not sufficient to orient technical experts towards the goals of these governance frameworks. By necessary, we mean that without these virtues, engineers and other experts would be in most cases unable to contribute to the goals of the frameworks. According to our argumentation, the integrative experts must embody different kinds of virtues or character traits. We thus set out to establish a tripartite theoretical grounding for the virtues that are empirically observed to be practiced by scientists and engineers who participate in a coordinated series of studies that investigate capacities for socio-technical integration at the micro-level [24].

Philosophers identified two kinds of virtues: epistemic and moral virtues. Accordingly, two philosophical subfields evolved: virtue epistemology and virtue ethics. However, aside from these two kinds of virtues, there is an overlooked yet important third kind of virtue that includes such traits as problem-solving competencies, collaboration, and creativity. These virtues are related to what one achieves in practices of innovating, designing or producing things, and accordingly we call them "poietic" virtues. The virtue of creativity is strongly related to innovation and so the link to RI is immediately evident. (One might ask whether creativity cannot also be regarded as an epistemic virtue. A recent publication seems to support such a view. Matthew Kieran [25] discusses "epistemic creativity." Kieran, however, simultaneously states that not all interpretations of creativity have to take creativity as epistemic creativity. In this paper, we focus on such an interpretation of creativity that takes it to be not an epistemic virtue.)

Against the typically narrower focus on moral virtues alone, we stress that the landscape of virtues is much broader. The primary claim we advocate in this paper is that moral, epistemic, and poietic virtues all belong to the required virtues of technical experts and engineers who participate in the integrative activities and aspirations that governance frameworks, such as SD, TA, and RI, are concerned with. Additionally, we claim that it is possible to engage all three kinds of virtues in a way that advances the goals of transformation research through a philosophical-reflective approach.

The paper proceeds as follows. First, we present an interpretation of transformation research in Section 2. Afterwards, in Section 3, an empirical approach in light of this specific interpretation of transformation research is outlined, the method of Socio-Technical Integration Research (STIR). In Section 4, we submit theoretical reflections on virtues in light of the philosophical approaches of virtue epistemology, virtue ethics, and the philosophy of technology and engineering. The contribution of this paper is the emphasis on the neglected third category of virtues; therefore, poietic virtues are discussed in Section 5. A potential objection is raised in Section 6 before the paper concludes in Section 7.

2. Transformation Research

As mentioned above, our interpretation of transformation research applies broadly to the aforementioned governance frameworks. That said, we begin our discussion of this topic by taking up and expanding upon a recent contribution to the debate about methodologies for sustainability research. Arnim Wiek and Daniel Lang [26] provide a detailed methodological picture that builds on the idea that transformations have to be promoted by providing solution options. Wiek and Lang make a distinction between "descriptive-analytical" and "transformational" forms of sustainability research. They propose to follow such latter approaches to transformation research. They claim that sustainability research is better off following the transformational option because this option not only describes the same sustainability problems as descriptive-analytical approaches, but also creates room for solutions to these problems. Drawing on Armin Grunwald's definition of actionable knowledge [27], Wiek and Lang give three requirements for their proposed interpretation of transformational research.

> Three general methodological requirements apply to transformational sustainability research: first, transformational research needs to apply *suitable methods* [. . .] that generate [different types of actionable] knowledge *as ingredients of* solution options. [. . .] [S]econd, transformational sustainability research needs to employ *methodological frameworks* that combine different types of methods to generate such multifaceted actionable knowledge. [. . .] [T]hird, transformational sustainability research is concerned with real-world problems and aims at actionable knowledge that stakeholders are willing and able to implement. Therefore, there is broad agreement that such research has to be carried out in *close collaboration* between scientists and nonacademic stakeholders from business, government, and civil society. (p. 33, emphasis in original) [26]

In principle, we agree that Wiek and Lang's three requirements are necessary for conducting transformation research. Furthermore, we suggest that transformation research can be conducted in many fields and applies to the various governance frameworks already mentioned. Additionally, we wish to expand upon Wiek and Lang's framework by proposing a form of research that sits between their two distinctions. This hybrid form of research is transformational since it accords with their three requirements; but it is also closer to descriptive-analytical approaches since it entails a form of philosophical reflection that is largely descriptive and that is pursued primarily to enhance understanding. In that sense, we expand upon their framework by proposing a third, hybrid form of research that includes the three requirements for transformational research, but adds a fourth requirement: the requirement of using philosophically induced reflections in the context of dialogical exchanges.

Such philosophically informed transformation research is, we suggest, a distinct form of philosophical-reflective approach that can be distinguished from other more intentional and directed transformational approaches to change groups or societies. (We distinguish this reflective approach from a more formal philosophical-analytical approach. It is a question of further research to study how such a philosophical-analytical approach is similar to or different from the descriptive-analytical approach discussed by Wiek and Lang.) The philosophical-reflective approach is meant to be a modest proposal that, nevertheless, opens up the space of possibilities by starting on the micro-level of individual researchers that can make changes in their methods of research. To do this, we focus on empirical examples in which dialogue and reflection are shown to lead to observable transformations among individual actors, in the next section. We analyze these micro-level transformations using the philosophical notion of virtues. We show not only that there are identifiable virtues that underlie recognizable patterns of transformation in transdisciplinary research, but also that there are different kinds of virtues that correspond to stages within the patterns. In the end, we seek to contribute to the theory and practice of transformation research and to highlight the transformational power of philosophical dialogue, in which reflection itself is a potential resource for change.

3. An Empirical Perspective: STIR and the Virtues

Socio-Technical Integration Research (STIR) was originally developed to identify and assess opportunities for scientists and engineers to influence science and innovation decisions in accordance with both scientific norms and societal concerns [28]. A STIR researcher works with technical experts in their workplace (e.g., a university or industrial laboratory) and discusses the decisions that they are making "midstream", i.e., while they are researching, designing, developing, or procuring technology. STIR inquires into the nature of science and engineering research decisions that may or may not take socio-ethical dimensions into account. The immediate goal of the inquiry is not to influence but to assess the capacity of technical experts to respond to socio-ethical considerations by "modulating" their material, design, and strategic practices [29].

STIR probes capacities for socio-technical integration ("any activity whereby technical experts take into account the societal dimensions of their work as an integral part of that work" [2]) by mapping technical activities in real-time with a "decision protocol" [30]. The protocol helps structure, guides collaborative inquiry and is comprised of four components, each of which corresponds to a particular set of questions, as well as to one of the four capacities that eventually find expression in the dimensions of a widely recognized framework of responsible innovation (see Table 1 and also see [31,32]).

Table 1. STIR Decision components and corresponding capacities.

Decision Component	Philosophical-Reflective Question	Capacity Probed
Opportunity	What are you doing?	Reflexivity
Considerations	Why are you doing it?	Inclusion
Alternatives	How could you do it?	Responsiveness
Outcomes	Who might care?	Anticipation

The protocol is used to structure regular dialogues (the connections to Socratic dialogues and practices are developed in a working paper by Antonio Calleja-Lopez and Erik Fisher [33]) for a set period [28,30], and the results are qualitatively analyzed using the midstream modulation analytical framework [24,29,34]. STIR studies have empirically documented three typical types of modulations: Reflexive learning, value deliberations, and practical adjustments. Reflexive learning consists of heightened, often metacognitive, but also affective, awareness of one's own values and assumptions in relation to others; value deliberations, in which social, ethical and related concerns are clarified, expanded, critiqued or reevaluated; and practical adjustments, which consist of incremental material, strategic or behavioral changes in technical projects, processes, and organizations [35].

Participating technical experts voluntarily choose to enact modulations, rather than being encouraged, nudged, coerced or otherwise assisted to do so by the STIR researcher. STIR thereby assesses expert capacities in response to Mitcham's *plus respicere* injunction during their technical work [4], cf. [36,37]. Numerous STIR studies not only document technical experts "taking more into account" in ways that modulate their technical work, they also suggest that the dispositions of the experts undergo subtle but meaningful changes in correlation to the modulations, e.g., [24,30,34,38–43].

In short, each of the three typical results appears to coincide with the exercise of a specific virtue [44]. Instances of reflexive learning are often conditioned by an increase in *curiosity* about socio-ethical issues or the technical expert's own roles, identities, practices, and relations within broader social and ethical systems. Value deliberations tend to be attended by an increase, not just in curiosity but also in *care* regarding the stakeholders involved. Finally, in making practical adjustments, technical experts typically generate and act upon new ideas to solve problems, suggesting an enhanced *creativity*.

We now inquire into the status of *curiosity*, *care*, and *creativity* in terms of virtues. In attempting to understand experts' capacities to influence science and innovation decisions and directions in accordance with both scientific norms and socio-ethical concerns, and building on the results of STIR studies, it seems evident that these three dispositions of character can be viewed as virtues that are required for any responsible, sustainable, or alternative form of integrative practice in science and engineering. Without being curious, one would not be motivated to ask penetrating research questions or identify underlying problems in the first place. Without some form of care (for others), it is difficult to imagine experts voluntarily responding to concerns of various stakeholder groups cf. [23]. Additionally, without being creative, technical experts would not be able to develop new solutions to identified problems. In short, we suggest that these three virtues that correspond to midstream modulation sequences are necessary conditions for integrative micro-level research and innovation practices. Of these three virtues, it seems clear that curiosity and care signal the presence of epistemic and moral virtues, respectively, as described by numerous scholars, e.g., [10,11]. What is often overlooked in the literature, however, is that an additional type of virtue seems to be at work here: poietic virtues, such as creativity.

4. A Theoretical Perspective: Virtue Epistemology and Virtue Ethics

Three philosophical lines of argument form the basis for the theoretical grounding of the virtues an integrative expert should possess or cultivate. The first two stem from established traditions in the philosophical fields of epistemology and ethics, respectively. The third is the specific contribution of this paper, which can be seen to grow out of recent discussions in the philosophy of technology and the philosophy of engineering cf. [45,46]. In general, the cultivation of virtues in order to lead a good life is the main theme of any philosophical approach focusing on virtues. Historically, this discussion of the good life is already present in discussions of the excellence of persons in Aristotle's *Nicomachean Ethics*. There, a clear focus on the moral aspects was set, but the virtues were not exclusively seen as moral virtues. According to Aristotle, there are "ethical" and "dianoetical" virtues. These virtues are characterized as being either related to the practical or the theoretical domain of life. One virtue, "phronesis," has an important function of building a bridge between the practical and the theoretical domain cf. [12].

(i) Virtue epistemology may provide some support for the first type of virtue, represented here by the virtue of curiosity: epistemic virtues such as open-mindedness or intellectual courage seem to be among the required virtues of researchers as they are important for anybody who is seriously inquiring about a topic. These two examples of so-called intellectual virtues are not the only virtues discussed in contributions to epistemology. Nowadays, an important distinction is made between "reliabilist" and "responsibilist" virtues [13]. The former are cognitive faculties such as good memory or reasoning skills; the latter are character traits of human beings. Both are oftentimes conceptualized as competencies of epistemic agents. Additionally, already in Aristotle's *Metaphysics*, one finds the insight that human beings are curious by nature [14]. We take curiosity as the most basic epistemic virtue that the technical expert already has as a human being. Because one has to be curious to start an inquiry, in the first place, we treat this very general and basic virtue as the prototypical epistemic virtue.

(ii) Approaches in virtue ethics stress that moral virtues are important for leading a good life. For instance, Vallor [47] argues for so-called "technomoral" virtues being important virtues of the 21st century. She not only calls for virtues such as honesty, courage, and care but also for nine other core technomoral virtues. Vallor presents a list of twelve virtues that foster human flourishing on a global and local level and argues that those virtues are needed in order for the human species to survive the 21st century.

(iii) Aside from epistemic and moral virtues, there are other virtues such as problem-solving competencies, the ability to collaborate and to foster collaborations, and creativity. These virtues of the potential third kind are related to what one achieves from a maker's perspective, and accordingly we call them "poietic" virtues. In a recent paper, Luciano Floridi [15] argues that "maker's knowledge" is a category of knowledge that has been neglected for a long time and that should be put on the agenda of epistemology again. At one point, he calls it "poietic knowledge," a phrase that we take to be suggestive of the poietic virtues we discuss. Floridi argues that maker's knowledge is a further category of knowledge, beside knowledge that something is the case or knowledge of how to do something. In the present paper, however, we hold that there is a difference in kind between epistemic and poetic virtues as connected yet distinct modes of human capacity. While not exact, such a distinction is somewhat analogous to the distinction between formal knowledge and tacit knowledge.

In the next section we argue that all three virtue types must be exercised in projects aimed at responsibly and sustainably researching, designing, and developing technologies. After first focusing on the connection between epistemic and poietic virtues, we turn to the connection between moral and poietic virtues as our main interest.

5. The Case for Poietic Virtues

5.1. Epistemic and Poietic Virtues

There is a close connection between epistemic and poietic virtues as seen from the contemporary emphasis on innovation. As engineers and other experts are usually faced with a demand for novel solutions to technological problems by different types of stakeholders, they need to be innovative, which includes being creative and many other virtuous character traits that are required for them to successfully carry out their work. Engineers have to be not only knowledgeable about the basic theoretical principles and disciplinary skills, they must also to be able to make and create things, which often involves engaging in improvisational [48] and other uncertain and "messy" endeavors. Even if there were no demands for innovating responsibly, they would still have to cultivate these epistemic and poietic virtues in order to develop solutions to design problems. Therefore, one might ask whether some of the virtues are already necessary for any innovation project, including irresponsible ones.

For example, think of Wernher von Braun, the chief engineer of the National Socialists during World War II who was in charge of the development of the V-2 rocket. Below, we return to this question of how to deal with potential uses of engineering products for immoral and socially irresponsible purposes by inviting the reader to imagine two hypothetical engineers—Wernher van Red and Walda van Green—that resemble the historical engineer, von Braun.

If it would be feasible to neglect the moral perspective, then this might be the case for poietic virtues such as creativity. However, given that moral values need to be considered in the context of technological innovation which involves uncertainties and that the luxury of the so-called value-free ideal [49] often ascribed to scientists cannot be attained by engineers and other technical experts, it is reasonable to require these researchers to possess or cultivate moral virtues.

5.2. Moral and Poietic Virtues

Because technological and innovative endeavors that involve uncertain outcomes require moral virtues such as care or other character traits of the techno-moral kind, we argue that it is reasonable to ask for moral and poietic virtues in the context of endeavors related to governance frameworks such as SD, TA and RI. This is clear from the emphasis in RI on both the "inclusion" of diverse value considerations and on the "responsiveness" of innovation processes to such considerations [6]. In short, moral and poietic virtues go hand in hand in order to innovate responsibly. The poietic virtues are not only closely connected to epistemic virtues, they are also closely tied to moral virtues. Again, we use the example of care (for others) as the paradigmatic moral virtue relevant in contexts of innovation. The question already posed above can be reformulated in terms of this character trait: is care a necessary condition for orienting towards the goals of the governance frameworks such as responsible innovation or is it already a necessary condition of any innovation? Building on others' arguments [6,50,51], we submit that care is a necessary condition for responsible innovation, including within micro-level practices. For example, Xavier Pavie [52] argues that care requires the consideration of "the essential interdependence between the innovator and the citizen." Similarly, care for the public safety of a proposed technology is something engineers and other experts are arguably already ethically (according to codes of conduct), and in some cases legally, required to exercise. (It is tempting to require care as a necessary condition for any innovation, but we want to stay uncommitted to this stronger thesis concerning care and the moral virtues.)

5.3. Wernher van Red and Walda van Green

There is a further case for the poietic virtue of creativity. To discuss this argument, we engage in a thought experiment. Suppose that there are two engineers, both of whom are exemplars of moral and epistemic virtues. Wernher van Red and Walda van Green are both working on the development of technology X. By being morally and epistemically virtuous, van Red and van Green each practice admirably the moral virtue of care and the epistemic virtue of curiosity. Technology X, which both are working on, has a number of anticipated beneficial uses, A-D. However, there is one potential use of the technology, use E, that would have severe moral consequences. Van Red makes an effort to anticipate the uses and consequences of technology X. He considers uses A-D and he even can imagine further uses F-H that are quite unlikely to be made of X. Van Red exercises care for the people who might be affected by X and he is also curious to find out about the potential further uses and consequences of X. Unfortunately, he is not very creative. Because of this, van Red cannot imagine use E of X. He develops technology X, and it is used for E, which has the effect of perpetuating the unfair treatment of a citizen group Z.

Walda van Green, on the contrary, is creative. She exercises care and is curious to the same extent as van Red is. Thus, van Green also thinks about the uses and consequences of X. She identifies A-D and can also think of F-H. However, because van Green is creative, she can imagine use E. As a result, van Green does not develop technology X, which van Red does develop. Instead, she develops technology X′, which is designed differently as a result of anticipating use E and as a response to the concerns of citizen group Z. Her results do not perpetuate the unfair treatment of citizen group Z, and for our little story to have a happy ending, the bad outcome is prevented due to van Green's poietic virtue of creativity.

6. Collective Virtues?

Up until now, we have considered the virtues in the classic sense of individual character traits that are either possessed or not possessed by the individuals in question. However, as our thought experiment implies, individuals do not develop technologies alone or as a homogeneous group, and responsible innovation is a collective endeavor and thus not a simple matter of there being single agents who are solely responsible [6].

Let us therefore turn to an important objection against the proposed claim that virtues are necessary to orient engineers and other technical experts towards the goals of the governance frameworks. With respect to scientific inquiries there are objections to the claim that epistemic virtues are necessary for scientific success. Cedric Paternotte and Milena Ivanova [16] point out that, with the help of historical cases, that vices instead of virtues promote certain successes in science. Their focus is constituted by questions about which theory to choose in cases of insufficient evidence. It might be the case that a similar objection could be run against our proposal. Isn't it the case that particularly successful technical experts are rather vicious instead of virtuous persons? In the case that such a vicious person contributed to a project in responsible innovation, for example, wouldn't that be a counter example to our claim about the virtues being necessary for orienting the goals of the governance frameworks?

If the virtues are to be considered only as character traits of individuals, then this seems indeed to be a problem for the proposed account. However, if the virtues can be understood to be somehow social, then one answer might start with the assumption that a group of technical experts that contain vicious individuals might nevertheless count as virtuous on a group level. Group virtues have been discussed in social philosophy, social epistemology, and business ethics in terms of "group moral virtues," "collective epistemic virtues" and, in the case of creativity, "collective virtues" cf. [10–19,44,51]. Granted that there are these group virtues, a reinterpretation of such a case involving vices could be given. Some individuals may lack virtues and they may even be vicious, nevertheless, the group they are in is still virtuously performing its function in the research and innovation process. The focus is still on the micro-level and not on institutional mechanisms or processes per se, but this focus is adjusted from the single considerations of individuals to the social group that the individuals are part of.

A further question is how exactly to interpret such a group virtue. Is it, for example, constituted by an aggregation of the virtues of the individuals, or is the group virtue in a sense independent of the virtues of the individuals? While a full analysis of this important question is beyond the scope of the present inquiry, we do note that Vincenzo Politi and Alexei Grinbaum make a case for aggregate virtues by suggesting that a distribution of virtue-ethical labor, in which only a subset of scientists and engineers possess or practice the necessary virtues, is sufficient to ensure responsible innovation [23].

7. Conclusions

This paper proposed a hybrid interpretation of transformation research in the context of normative governance frameworks, such as sustainable development, technology assessment, and responsible innovation. We conducted a theoretical exposition of the capacities that are found to be exercised by scientists, engineers, and other technical experts who participated in prior empirical studies that employed STIR dialogues. Using the philosophical subfields of virtue epistemology, virtue ethics, and the philosophy of engineering we identified three individual virtues thought to be consistently present during successful modulations of research and innovation pathways. Additionally, we found that each of these three individual virtues belongs to a separate kind of virtues. We thus sought to contribute both to the fields of epistemology, ethics, and the philosophy of technology, as well as to the practical design and assessment of projects and programs intended to bring about good results of transformation research that require the virtuous participation of scientists, engineers, and other technical experts.

According to the proposed philosophical-reflective approach that studies patterns of transformation processes on the micro level, virtues are forms of excellence that scientists, engineers, and other technical experts need in order to foster socially and environmentally responsible change. In other words, transformation research requires integrative experts who possess and exercise integrative virtues. While this paper did not address the question of how to exercise these virtues, it did identify not only the virtues but also the kinds of virtues that policies, organizations, and projects should seek to cultivate.

The proposed hybrid approach of transformation research emphasized the role of philosophical reflection as a way to cultivate these virtues among such technical experts. Results from the STIR studies suggested the importance of three particular character traits among such technical experts who, in accordance with the injunction *plus respicere*, did in fact "take more into account" as a result of reflective dialogues. Accordingly, we categorized these traits into three distinct kinds of virtues. Aside from the theoretically accepted categories of moral and epistemic virtues, we stressed the importance of poietic virtues among the necessary attributes of agents involved in transformational activities. Our analysis has implications not only for the implementation of the mentioned governance frameworks and for the management of transformation research projects, but it also may have implications for scientific and engineering educational curricula, engineering association codes of conduct, and the design and implementation of industrial programs in, e.g., ethical and responsible AI. In short, moral virtues cannot be exercised in isolation from either epistemic or poietic virtues; rather, all three must be exercised in an integrated manner. Moreover, these integrated virtues must be exercised not merely as isolated individual character traits but at more aggregate social levels.

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