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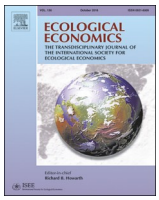

Why cross and mix disciplines and methodologies?: Multiple meanings of Interdisciplinarity and pluralism in ecological economics

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A B S T R A C T

Ecological Economists disagree much about their field and its relationship to mainstream economics and to policy. One reason for these disagreements is that the field pursues multiple goals under the headings of "interdisciplinarity" and "transdisciplinarity." At least four distinct goals may be pursued under these labels; brainstorming and borrowing for novel combinations of ideas, building new sub-disciplines at the juncture of existing disciples, bringing multiple fields into methodological and theoretical coherence, and involving science in solving social problems. The latter two draw the most controversy. Ecological Economists desire reforming Economics and other social sciences by integrating theories from ecology and physics, but there are multiple means of doing so. Likewise, many seek to create new ways for academic knowledge to be better utilized in public decision-making, but perspectives differ here as well. These represent fundamentally different axes of disagreement but are not always treated as such. Ecological Economics continues to contain a broad range of perspectives, some contradictory, for a rather small research community.

1. Introduction

In the decades since its founding, Ecological Economics (EE) has strived for not only new ways to understand economy-in-society in the rest of nature, but new ways to conduct research and use science for the public good. Early cross-disciplinary collaboration has spawned several successful research programs, developed indicators used by governments and individuals, and supported prominent academic careers. Many practitioners also see it as a project for socio-ecological transformation (Dube, 2020), where it has made much less progress- indicators of environmental challenges have mostly deteriorated. It has also made little progress in radically altering economic thinking- published work in the journal *Ecological Economics* has moved more towards the discourses and methods used in mainstream economics (Castro e Silva and Teixeira, 2011). A wing of the field argues that EE has allowed itself to be coopted by mainstream economics, diluting its radical critiques (Spash, 2013), but this diagnosis is often unclear- scholars so implicated may also consider themselves harsh critics of the mainstream (e.g Farley and Washington 2018).

These conflicts within Ecological Economics can be better understood by examining long-standing confusion and conflict about the meaning of academic research and action which works to overcome the boundaries of discipline (supra-disciplinary). Since the dawn of academic disciplines, critics have promoted competing and contradictory visions of when, why and how to transcend disciplinary science.

First, I review the meaning of academic disciplines and how that informs different attempts to overcome their limitations. Second, I outline a taxonomy of intentions behind supra-disciplinary research. Third, I review how these intentions manifest themselves in Ecological Economics, exploring in greater detail conflicting ideas of what interdisciplinary synthesis, and action-oriented transdisciplinarity ought to mean in Ecological Economics. Fourth, I examine how "radical" interpretations of either of these intentions lead to very different critiques of mainstream economic practice. In summary, "Ecological Economics" has long been loaded with many different meanings, despite the relatively small size of its research community and functions more as a meeting place of several different perspectives than a unique perspective of its own.

2. Disciplinary and Supra-disciplinary Science

"Interdisciplinarity cannot live without the disciplines… You cannot cross boundaries if you don't know where they are." (Hunt, 1994, p. 1).

Since the founding of the field, Ecological Economists have argued for pluralist, interdisciplinary and transdisciplinary approaches to science (Costanza et al., 1991; Funtowicz & Ravetz, 1994; Max-Neef, 2005; Norgaard, 1989). This places EE in a long tradition of reactions to the fragmentation of academic knowledge in modernity.

Modern "disciplinary" science emerged in the 19th century, and the academy became increasingly professionalized, mirroring trends in

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society and law. Before this time, most research and teaching were conducted by generalists and amateurs without detailed training in their specific area of research. In earlier times, the only academic disciplines were theology, law and medicine (Klein, 1990, p. 20). Over time, the number of distinct specializations in academic knowledge has increased dramatically. Specialization has coincided with enormous progress in many scientific fields, but many academics have criticized this trend and fought against it.

By the early 20th century, a reaction calling for "interdisciplinary" science and education had formed. At first, this term and critique was mostly applied to scientific education (Klein, 1990) and migrated into the applied sciences a few decades later.[1] Since then, counter-movements have been described with numerous terminologies and taxonomies that are often inconsistent with one another. The lack of clarity in terminology begins with competing definitions of academic disciplines, then compounded by different conceptions of how the boundaries of disciplines might be crossed.

Dictionary definitions of scientific "discipline" are almost exclusively reliant on spatial metaphors, such as "field," (discipline, 2020a), "branch," (disciplines, 2020c)", or "area" (discipline, 2020b) of study. These metaphors evoke disciplines as static territories of knowledge, but boundaries are constantly in flux (Klein, 1990). Though perhaps academic disciplines *ought* to be bounded by deep ontological distinctions between their objects of study, this is not the case (Trowler, 2014).

", he dynamics of disciplinary science have been crucial to modern understandings of the history and philosophy of science, though many scholars did not use the term "discipline." Kuhn (1970) described how the narrowing of scientific inquiry under a disciplinary matrix has been both crucial to scientific progress and occasionally the primary hindrance to it. The "paradigms" of normal science not only sharply limit the objects of study for a researcher in a discipline, but also the questions she might ask, and the methods utilized. Lakatos (1970) added substantial nuance to this discussion by explaining that research programs are structured around claims held with varying degrees of dogmatism- from "hard core" claims that are never questioned to expendable "auxiliary hypotheses" that are easily modified or discarded in the face of new evidence. Both models emphasize methodological and theoretical consensus as a key functional trait of progressive scientific research, most of the time.

Krishnan (2009), gives six criteria for academic disciplines. A discipline shares (1) a body of specialist knowledge, concerning (2) an object of research (3) that is organized by a set of theories and concepts. Further, a discipline shares (4) research methods and (5) technical language and (6) is institutionalized through academic courses, departments and societies. Krishnan further notes that many disciplines do not meet all these criteria; some disciplines are more "disciplined" than others. Some of these disciplines see fulfilling these as a crucial project for their field, while others opt to self-consciously remain 'undisciplined.'

Similar to Krishnan, Donald, 2002) defines a discipline as "a body of knowledge with a reasonably logical taxonomy, a specialized vocabulary, an accepted body of theory, a systematic research strategy, and techniques for replication and validity" (p 8). More narrowly, Berger (1972) defines a discipline as "A specific body of teachable knowledge with its own background of education, training, procedures, methods and content areas. (23)" Trowler (2014) gives a very broad and social constructivist definition:

> *"Disciplines are reservoirs of knowledge resources which… condition behavioural practices, sets of discourses, ways of thinking, procedures, emotional responses and motivations… [leading to] structured dispositions for disciplinary practitioners." (They are characterized by) "common background knowledge about key figures, conflicts and achievements. Disciplines take organisational form, have internal hierarchies and bestow power differentially… (p. 1728)".*

The lack of consistent definitions leads to confusing descriptions. Stock and Burton (2011, p. 1099) refer to Political Ecology as a "transdisciplinary sub-discipline," while this journal describes *Ecological Economics* as an "inter-disciplinary field," which, given that field and discipline are synonyms, indicates an "inter-disciplinary discipline" or a "field between fields." These constructions are not necessarily in conflict- Ecological Economics is a partially institutionalized knowledge community built around shared theories and jargon but includes scholars and techniques from a wide range of academic traditions. EE has some characteristics of an academic discipline, but not others. Similar confusions arise in applied fields, which on the one hand, may meet most of Krishnan's requirements, yet also draw upon more basic research from several other disciplines (Bridges, 2006).

For the rest of this paper, I will use "discipline" in the fuzzy sense of Krishnan's definition, and will follow Balsiger (2004) in using the term "supradisciplinary" to encompass endeavors that are multi, inter and/or trans-disciplinary, in the interest of brevity.

2.1. Reasons and intentions for moving beyond academic disciplines

Calls for more interdisciplinary approaches are rooted in critiques of fragmented, reductionist, disciplinary science. Counter-movements to the specialization and fragmentation of knowledge have often hosted multiple distinct critiques and proposed solutions to the fragmentation of knowledge. These different critiques point to different proposals for supra-disciplinary science.

While they never used the term "interdisciplinary," the Vienna Circle of Logical Positivists was an influential early movement against the fragmentation of science. The Vienna Circle pursued "unity of science" with much disagreement as to its meaning. Some thought unity of science meant pure reductionism, linking all scientific laws to physics, while other held weaker versions. These weaker framings included the development of a single, universally applicable "scientific method," the creation of a unified language of science to allow clear communication across disciplines, or simply "the orchestration of the sciences" to allow pluralistic cooperation across sciences and with the general public (Kallen, 1946; Neurath, 1946).

In the early 20th century, scholars became interested in "interdisciplinarity," especially with regards to liberal-arts pedagogy (Klein, 1990). By the 1970s, interdisciplinarity was still most associated with general and professional education, but was increasingly used in basic and applied research as well (Berger, 1972). By this time, interdisciplinary activities were being pursued with several different goals, including: staking out new disciplines, meeting student needs for well-rounded education, professional training and problem-area focused research and education (ibid).

Later in the 20th century, "transdisciplinarity" came into use to describe activities with two distinct orientations; towards either concrete problems and actions and/or the unification of disparate scientific knowledge and activities. Paul and Hadorn (2008) define it based on real-world problems, as have several others. Many, especially scholars from the global south or other marginalized groups, approach transdisciplinarity as real-world problem-solving which embraces reformulations of problems by disadvantaged groups, influenced by thinkers such as Paolo Freire (1996) e.g. (Méndez et al., 2017). Scholars who discuss transdiscplinarity as unified inquiry include Piaget (1972, p. 138) who defined it as "a total system without any firm boundaries between disciplines", Miller (1982) who identified it with "overarching non-discipline bound thought models," such as Marxism or general-systems theory and Berger, who defined it as "Establishing a common system or axioms for a set of disciplines (1972, p. 24)." One of the first

[1] The term first appears in the journal *Science* in 1944 with Brozek, J., & Keys, A. (1944). General aspects of interdisciplinary research in experimental human biology. *Science*.

to use the term, Jantsch (1970), incorporated both of these elements, defining transdisciplinarity as an approach to science which coordinates all levels of the "education/innovation system" towards socially relevant goals.

Klein (1990, p. 64) argues that there are 4 primary types of discipline-crossing interactions- First, "borrowing", which can involve models, methods or concepts. "Solving problems" involves concrete issues rather than conceptual unification, such as using multiple disciples to formulate a city plan or develop a new technology. "Increasing consistency of subjects or methods," can involve coordination of research along a shared border, such as recent interchanges between economics and psychology. Lastly, "emergence of an interdiscipline" describes a process which created many of the existing fields of the natural sciences, such as physical chemistry, molecular biology and radiation ecology, as well as activities spanning the human and natural sciences, such as "developmental psychobiology." An inter-discipline often emerges as a later stage of increasing consistency of subjects and methods. Klein separates these from "transdisciplinary" frameworks, which aim to coordinate activities across many different (or all) disciplines under a shared paradigm, after Miller (1982), and including Jantsch's vision (1970) as the most ambitious version of this.

Bruun et al. (2005, p. 90–91) note that work which crosses disciplines can be distinguished by the degree to which it is *epistemologically oriented,* seeking to generate knowledge and theory, vs *instrumentally oriented,* where the goals pursued are "extra-scientific", non-academic and practical. Similarly, Robinson (2008) gives this dichotomy as "discipline-based" versus "issue-driven" versions of interdisciplinarity. These differences also emerge in different uses of the same words, for example, between transdisciplinarity as "over-arching thought models"(Miller & Miller, 1982) versus transdisciplinarity as generating problem-oriented knowledge (Pohl & Hirsch Hadorn, 2008).

Here, I classify the motivations, goals or orientations of supra-disciplinary science as:

1. to brainstorm, borrow and make new connections
2. to create new sub-disciplines
3. to create consilience and consistency between disciplines
4. to use knowledge to support action and real-world problem-solving

This taxonomy is similar to Klein's, but number 3 contains a spectrum of integration, from attempts to make more coherence between two disciplines to overarching thought-models which cover many or all academic disciplines.

3. Ecological Economics and the 4 goals of supra-disciplinary science

Ecological Economists have complicated relationships with the idea of scientific disciplines. The field is partially a reaction to the problems of disciplinary science, but participants have also worked to build many of the trappings of a scientific discipline. These include the mundane and institutional—Ecological Economists created an academic society, a journal, academic institutes and university programs and courses. Additionally, many scholars seek greater definition and coordination in its object of study, technical language, theories and methods. The interplay between discipline-building and anti-disciplinary thinking in the field is key to understanding it.

The EE discourse on the practice of science is dominated by three overlapping and related dualisms: normal/post-normal, methodological monism/pluralism, and disciplinary vs inter-or-trans-disciplinary. These dualisms mostly map onto one another, but incompletely. For Kuhn, Normal Science is defined by a well-articulated "disciplinary matrix", including clear articulation of methodology. In the realm of basic research, normal science is disciplinary, methodologically monist science. Likewise, Funtowicz and Ravetz (1991, 1994), when contrasting "post-normal" science with "normal," emphasize the importance of multiple methodological perspectives and while not using the term "transdisciplinary", they argue that "Resolving such issues cannot be accomplished even by calls for 'multi-disciplinary' research (1994, p 204)" because greater coordination is needed.

Different researchers and camps in the Ecological Economics community have pursued all the above goals at various times. The questions of which goals are most important and the best ways of achieving them have been contentious, however. The first two goals, which are limited in their scope, and largely accept the broader structure of current science, have clearly been areas where Ecological Economics has had some success. The latter two goals, which represent attempts to remake both the current structures of knowledge and the use of knowledge in society, have experienced more conflict and only modest progress.

Spash (2013) argues there are three distinct camps within Ecological Economics. To Spash, New Environmental Pragmatists are defined by environmentalist goals without serious methodological consideration, New Resource Economists by acceptance of mainstream economic methods and a (tacit) neopositivist philosophy of science, and Socio-Ecological Economists by a desire to revolutionize economic thought on scientific and ethical grounds. This ideal-type classification structures some arguments in the field, but positions in the field are much more plural. For instance, Spash and Ryan (2012) showed a large majority of Economists in three European conferences identified with a hybrid of 2 or more of these camps, and only insignificant fractions identified purely with the New Resource Economist or Pragmatist camps.

Presenting the field as involving multiple axes of disagreement may provide a better understanding of how Ecological Economists view themselves and reveal both unseen agreement and unseen disagreements. Below I briefly summarize supradisciplinary Ecological Economics as a forum for borrowing and brainstorming, and a nursery for new hybrid disciplines, then delve more deeply into the difficulties of the more ambitious supra-disciplinary goals of consilience and problem solving. In each case, I discuss how the camps proposed by Spash partially represent distinct perspectives on these questions.

3.1. Ecological economics as a forum for cross-disciplinary "borrowing"

The early practice of EE emerged as social and natural scientists tried to learn from one another. Like other periods in the history of science, ideas from one discipline were applied in a different one, providing novel insights, new metaphors, and possible research directions. This goal was explicit in the founding of the journal (Costanza, 1989), and is still defended. Costanza (2020, p 2) states that Ecological Economics "represented a commitment among academics and practitioners to learn from each other, (and) to explore new patterns of thinking", among other goals. Some economists searched for ways that the natural sciences could inform their inquiry, while natural scientists looked to apply their theories, frameworks and methods to economic systems, and both attempted to understand ecosystem management using economic methods New concepts included ecosystem services, natural capital, Georgescu-Roegen's imprecise yet rhetorically powerful appropriation of the concept of entropy, explorations of an "energy theory of value," and analysis of energy and material flows based in systems ecology. Likewise Ecological Economists have found inspiration in appropriating evolution and coevolution to understanding economic and ecological systems (Kallis & Norgaard, 2010; van den Bergh & Gowdy, 2000), in a long tradition of creative Economic thinkers (Schumpeter 1934).

3.2. Ecological economics as a nursery for new hybrid disciplines

Carving out new sub-disciplinary research programs and communities in the gaps and junctions between academic disciplines has long been identified as a key aspect of interdisciplinarity (Campbell, 1969), and for a time was considered the primary or only form of interdisciplinary thinking (Newell & Gagnon, 2013). While this definition of

interdisciplinarity has fallen out of favor, it was very prominent in the academy during formative years of Ecological Economics.

Several of the concepts developed in the "brainstorming" of early EE may still be sometimes identified as part of the field but appear to be Kuhnian "paradigms" or Lakatosian "Research Programmes," in themselves. These programs largely involve "calculations in nature" (Røpke 2005), and measurement or valuation of benefits from ecosystem services. These works are sometimes published in prominent scientific journals. These more 'disciplined' research programs are often fiercely debated within Ecological Economics, especially research in ecosystem services and their valuation (Farley 2018). The ES research program emerged from EE, but many more researchers identify with it than with EE,[2] and it is sometimes conflated with the EE as a whole (Nadeau, 2015). Smaller flourishing research programs relating to energy analysis, ecological-economic indicators and material flows at least partially trace their lineage to Ecological Economics. These programs can largely be tied to Spash's concept of a "New Resource Economics" in EE, though those programs which deal in only bio-physical quantities rather than dollars may find a home in any of his categories.

3.3. Areas of deep contestation in supra-disciplinary EE

In the projects described above, there has been real success in shallow, less-radical conceptions of supra-disciplinary practice. Interdisciplinary efforts resulted in borrowing, sharing and new fairly narrow research programs, exemplifying how working across disciplinary lines results in changes within scientific disciplines. Ecological Economics is much more unsettled with regards to the remaining two rationales for supra-disciplinary practice; high-level integration of methodology and epistemology and appropriate application of disparate thought models to social concerns. Recent contributions on the state of the field have completely emphasized one over the other, while others balance both. For instance, Melgar-Melgar and Hall (2020) argue for Ecological Economics as the bio-physically grounded scientific investigation of the economy, while in the same issue Herrmann-Pillath (2020) conceives of Ecological Economics as an "art" of building scientifically-grounded models alongside various social actors. While these activities may be complementary with one another, they are clearly distinct modes of academic work and suggest different choices about methodology and epistemology.

While various authors have used these terms in ways that contradict one another, I follow Baumgartner et al. (2008) who define interdisciplinarity as "fully integrated cooperation of the disciplines" (386) and transdisciplinarity as "the inter-connection of science and society" (387). I further specify this terminology to "integrative interdisciplinarity" and "action-oriented transdisciplinarity." Integrative interdisciplinarity describes projects to unify fragmented domains of knowledge and increase the internal consistency of science as an endeavor. Action-oriented transdisciplinarity describes the combination of knowledge which is currently fragmented and uncertain with socially-determined value-commitments to make tangible impacts.

3.3.1. Integrative Interdisciplinarity

As a project, integrative interdisciplinarity may seek to reduce fragmentation on some dimensions but create other forms of fragmentation. The successes of integrative interdisciplinarity tend to be less grand than those attempted within EE. Most prominently in recent years, the "cognitive revolution" combining neuroscience, philosophy, psychology and economics has scrambled disciplinary boundaries and unified previously disparate research programs. In many other cases, integrative efforts simply create new axes upon which science is fragmented. Interdisciplinary thought-models described as "Marxist", "critical" and "neopositivist" seem to simply replace one set of barriers with another; while Marxist Economists and sociologists may face few barriers to collaboration, Marxist and neoclassical economists face many. As Kallen (1946, p. 494) argued with regards to Unity of Science-without the power to suppress alternate viewpoints, "the fate of a universal language of science would be the fate of Esperanto. It would be just another language competing with its alternatives for survival… adding more differences to those already existing, not diminishing them." Inter-disciplinary work on the environment seems to fall into this trap— Political Ecology and Ecological Economics have evolved into distinct "disciplinary" communities, whose distinct perspectives need to be linked or synthesized (Kronenberg, 2013; M'Gonigle, 1999).

Ecological Economics is often articulated as an integrative project, promoting greater coherence between the social and natural sciences and enforcing the consistency of Economics with underlying physical laws (Brown & Erickson, 2014; Daly, 1997; Melgar-Melgar & Hall, 2020). Some scholars have objected to strong versions of this framing, most foundationally Norgaard (1989), who rejects any single paradigm: "If we hold to the belief that knowledge is accumulating to one congruent understanding, we will miss the insights provided by incongruent ways of knowing. (p. 53) "Others have seemed conflicted on this matter. For instance, in their textbook, Costanza et al. (1997) argue both that "Ecological economics is not a single new paradigm based in shared assumptions and theory" (p 58) but also for "general systems theory" (p 60) as a key, shared underpinning of EE. But even where EE scholars agree that the field seeks synthesis and consilience, there are many disagreements as to how this might be best achieved.

There are multiple competing meta-models for bringing the interacting disciplines in the social and natural sciences into better coherence with one another. In Ecological Economics, these include General Systems Theory and Critical Realism, though many in the community also write admiringly of E.O. Wilson's conception of "Consilience" which is linked to his conceptions of Socio-Biology (Brown & Erickson, 2014; Costanza, 1999). While each of these pathways might plausibly achieve a synthesis of social and natural sciences, these meta-models seem much more difficult to synthesize with *each other*. As such, the EE community engages in numerous debates and discussions of how best to integrate currently fragmented disciplinary knowledge into a coherent whole. Spash (2013) articulates a conflict between "New Resource Economists" and "Socio-Ecological Economists" who both seek to coordinate the social sciences with Ecology and bio-physical modelling, but upon very different epistemic bases.

3.3.1.1. Integration and enforcing coherence and non-contradiction.

Ecological Economists often assert the importance of consistency between the natural and social sciences. For instance, Spash (2012) argues for a hierarchical, nested ontology of molecular, biological and social sciences. Each level within has emergent properties, so is not reduceable, but also cannot contradict, the outer levels. Among the most important emergent properties of the social sphere is reflexivity,[3] the impacts of human beliefs on external reality (Soros, 2013) which is a fundamental discontinuity between the biological and social sciences.

Reflexivity lies at the heart of the problem of understanding whether social science claims are supported, allowed by or contradicted by the natural sciences. When evaluating whether a statement about human systems is possible or impossible or logically required within our understanding of the natural sciences, we need to determine

[2] For instance, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) boasts 2137 "experts," substantially more than the number of registered members of the ISEE. (~1200)

[3] One of the more dramatic examples of this reflexivity is "the Financial Instability Hypothesis" of Minsky (1992), which argues that the beliefs of regulators and traders about the stability of financial markets are largely self-negating: the belief that markets are stable can create instability, while the belief that markets are unstable can create stability.

whether that statement's truth is dependent on human ideas, beliefs and constructs. Ecological Economics, operating on the bridge between the natural and social sciences, usually appears to deal with situations where the extent of reflexivity is *unclear*. For Ecological Economics to succeed as an integrative paradigm, it thus must enforce criteria for determining which extrapolations from the natural sciences might be invalidated by reflexivity and which would not be. Where reflexivity is ignored, attempts to enforce the non-contradiction of the physical sciences by social sciences easily slip from trivial consensus to highly controversial extrapolations.

For instance, Ecological Economists often assert the impossibility of continued economic growth without unacceptably high materials use. Some have even supported the "peak oil" thesis that declining oil reserves will force major changes to world economies imminently (Curtis, 2009; Murphy & Hall, 2011). In essence, these Ecological Economists argue that the hybrid social-physical objects "economic growth" and "usable oil reserves" contain too little social content for their meaning to be radically altered by human ideas. Optimistic mainstream economists have tended to disagree. Both Solow and Stiglitz (1997) concede to Daly and Georgescu-Roegen that quantitative economic growth is unsustainable in the very long-term, due to the laws of physics but counter that this alone has nothing to add to research on economic growth on socially-relevant timescales. Likewise, they argue that while individual "resources" are subject to the laws of physics, the *concept of resources* seems to be highly reflexive. Ecological Economists point out that GDP growth has never "de-coupled"(Hickel & Kallis, 2020), and thus green growth is an extraordinary claim requiring extraordinary evidence. This line of argument does not require invoking "the laws of physics," which is neither necessary nor sufficient to making arguments about the short-term feasibility or desirability of growth.

Ecological Economists often find themselves on the opposite side of debates about consistency versus reductionism. Many associate themselves with the political left, which has long fought biological reductionism in the social sciences as apologia for racism, imperialism, sexism and fascism (e.g. Levins & Lewontin, 1985). Critical realist Socio-Ecological Economists will concede the trivial point that all human behavior is subject to the laws of biology but treat any specific inferences about possible or desirable forms of social organization drawn from this with enormous skepticism (Spash, 2012). Like neoclassical economists responding to biophysical criticisms, they demand that extrapolations from the natural sciences to the social world be critiqued and justified in the terms of social science.

In Spash's typology, the quest for a more unified integration of the natural and social sciences is largely associated with the realist Socio-Ecological Economists. However, E.O. Wilson's *Consilience* (1999), favorably cited by some in EE (Brown & Erickson, 2014; Costanza, 1999), argues that integrating the social and natural sciences should draw heavily on mainstream economics. Wilson argues that mainstream economics is the social science "best poised to bridge the gap to the natural sciences" (p. 212) due to its reliance on mathematical models, while pointing to weaknesses that could be solved by behavioral economics and linkages with ecological sciences This points to the possibility of integrative New Resource Economics. The pragmatist position is either agnostic on the unification of knowledge, believes it to be unlikely, or to be a distraction.

3.3.2. Problem and action-oriented transdisciplinarity

Ecological Economics is concerned with a set of environmental and social problems, and Ecological Economists want to help with tangible progress on these issues. These problems have social, biological and physical dimensions, which necessitates approaches traditionally associated with many different scientific disciplines. Costanza (1991) argues transdisciplinarity means that Ecological Economics is "a pluralistic way of looking at problems" that is relatively unconcerned with "the particular intellectual tools… used to solve them and arbitrary intellectual turf boundaries." (p. 353) Relatedly, several of the reasons that Noorgard (1989) gives for pluralism relate to this goal, he argues that it "prevents brash action," "can help sustain biological and cultural diversity" and "promotes participation."

Problem and action oriented transdisciplinarity leads to a different set of challenges than integrative interdisciplinarity. First, the key normative goals of Ecological Economics- "Sustainability" and "Justice" are subject to multiple, competing interpretations. Second, action-oriented researchers must, explicitly or implicitly, choose some actors as legitimate stakeholders or representatives if they wish to produce knowledge that is useful and actionable to stakeholders or decision-makers. Additionally, the EE community disagrees over whether, and to what extent, science can provide definitive solutions to environmental policy problems. Problem-oriented transdisciplinarity thus constitutes a different axis of disagreement; all may desire engaged science, but this makes debates about with, for whom, and to what end science should be engaged all the more important.

Ecological Economists have adopted a range of approaches in selecting stakeholders to work with and support decisions for. Some have been very willing to work alongside government and business to create decision-support tools (Kubiszewski et al., 2013; Turner et al., 2010) while others have more closely aligned with radical social movements (Martinez-Alier et al., 2011). When researchers attempt to conduct research relevant to policy, they implicitly affirm the legitimacy of the policymakers they engage with. This makes choices to engage with policymakers potentially fraught.

When researchers work with policymakers, they are collaborating with public power that may be less than legitimate. Working towards decision-support for business and government runs the risk of uncritically accepting the problem-formulations of already-powerful actors, and thus reducing the potential for EE to promote justice and sustainability. All governments that Ecological Economists work with face some challenges to their legitimacy. For instance, Ecological Economics ideas are becoming increasingly influential in China, integrated into wide-ranging sustainability policy from a centralized state with no opposition party. Ecosystem services research in regions where ethnic minorities are systematically excluded from decision-making seems obviously incompatible with values pluralism, or human rights generally. Ecosystem Services research can encounter similar problems in titular democracies, where the values of vulnerable groups may be ignored or underweighted for many reasons, including the perverse over-weighting of affluent peoples' values (Matulis, 2014; Spash, 2008). Other Ecological Economists align their work with local environmental justice movements and view centralized attempts at "sustainability" with enormous skepticism (Temper et al., 2018). Such skepticism decreases the potential of scholarship having large direct societal impacts, for better and worse.

Lastly, Ecological Economists have long disputed the extent to which science can provide answers to policy quandaries. Many ecological economists have argued that science cannot drive policy, researchers argue for bringing science to policy and action through "weak comparability of values" (Martinez-Alier et al., 1998), "values pluralism" (Gowdy & Erickson, 2005) and deliberative democracy (Wironen et al., 2019). At the same time, the field has also promoted aggregate well-being/sustainability indicators such as GPI (Fox & Erickson, 2018) and ecological footprint (Wackernagel & Rees, 1998) which conceal highly political value-judgements, and arguments that "nature" imposes "limits" on economic activity (Georgescu-Roegen, 1971; Goodland, 1992). Like many in the environmental movement, our community often is drawn to "the use of science to 'compel' decision by the sheer strength of 'facts'" and to seek policy relevance through producing tidy numbers (Saltelli & Giampietro, 2016). Many other ecological economists whole-heartedly reject this (ibid.) Likewise, some ecological economists have turned against the notion of ecological limits, instead emphasizing social values and democratic choice (Kallis, 2019). With human activities increasingly perturbing the earth system, assessments of hard-to-measure risks are hard to disentangle from value-judgements

about the right level of collective risk-tolerance. (e.g. Steffen et al., 2015).

The disparate approaches to action-from-science in EE are exemplified in recent contributions to this journal. For instance, Rees (2020) argues that the "global community should… conceive and implement a global fertility strategy to reduce the human population to the two billion people" that he believes the planet can sustain, implying a radical centralization of global political institutions. On the other end of the spectrum, some seem to abandon policy solutions altogether while preparing for socio-environmental collapse (Hagens, 2020).[4] Intermediately, contributions examining or promoting incremental and technical policy changes are too numerous to count. Degrowth scholars, on the other hand, often seem to reject policy formulation as a goal of research altogether, deferring to social movements and deliberative democracy (Hanaček et al., 2020).

In Spash's typology, members of all three groups have positions on issues of science-policy integration. New Resource Economics seems to take the existing policy-advice process for granted and as essentially acceptable. Socio-Ecological Economists, if broadly defined, have various viewpoints on how to articulate value-laden political conflicts and especially how to raise up the voices of groups not currently represented in the policy process. Pragmatists appear to often take current policy-making processes for granted to achieve sustainability goals (e.g. valuation to fit into cost-benefit analysis), and also may assume universally shared values and adopt unifying rhetoric of win-win solutions- as when Costanza (2020) argues that Ecological Economics can help to achieve "the Future We All Want."

3.4. Different pluralisms for different purposes

Table 1 summarizes some major points of conflict in these two endeavors.

Ecological Economics has had successful pluralism in its role as a meeting point between ecology and economics and has helped to spawn more narrowly-focused research communities of around "hybrid subdisciplines." On the other hand, there has been little resolution with regards to whether Ecological Economics can become single a coherent scientific framework and if so how, and how science should interface with public decision-making and society more broadly. Ecological Economics has succeeded in the easy tasks of supra-disciplinary science but is divided on the harder ones.

3.5. Different supra-disciplinary goals imply different critiques of economics

Within EE, both integrative interdisciplinarity and action-oriented transdisciplinarity exist on a spectrum from those that imply fairly mild critiques of status-quo science and policy, to those that direct deeper and more fundamental critiques. Critical Realist socio-ecological economics strives for an over-arching thought-model capable of "disciplining" economic practice away from mathematical formalism and econometrics. Post-Normal science, on the other hand, focuses considerable attention on the social organization of science and the ways that scientific knowledge is used or misused to define and solve social problems. These two perspectives give distinct critiques of mainstream economics. Conversely, Post-Normal science advocates claim that when studying sustainability challenges "invoking 'truth' as the goal of science is a distraction, or even a diversion from real tasks" (Funtowicz & Ravetz, 2018, p. 2), clearly at odds with "realist" critiques of mainstream economics.

Critical Realist critiques of mainstream economics argue that current economic science produces illegitimate theory and expertise in the economic domain, but that by adopting a better ontology of social systems, economics can produce truer theory and better experts (Lawson, 2013; Spash, 2012). Such a critique is "interdisciplinary" in the sense that it calls for incorporating insights from across existing academic disciplines but like many integrative interdisciplinary efforts, it seeks to "discipline" scientific practice with internally governed standards of scientific quality. The thrust of this effort points towards critical realist economics eventually developing most of the functions of an academic discipline.

The post-normal critique of mainstream economics takes a very different form. The failures of economic policy advice cannot be blamed merely on bad theory or incorrect ontologies. Rather, the problem can be rooted in the interaction between science and society. Issues include expectations that scientific expertise can provide definitive answers to pressing social problems (Saltelli & Giampietro, 2016), the cooptation of scientific theories by social actors (Fischer, 2000; J. Ravetz, 1994; J. R. Ravetz, 1973) and the internal social dynamics of science (Benessia et al., 2016). Such a critique moves to an approach to science-for-action that is transdisciplinary in its innate pluralism. The need to incorporate knowledge rooted in multiple methodologies and standpoints is permanent, rather than a passing phase before a new synthesis.

A post-normal philosophy of science focuses little on problems of "demarcation" (Cohen & Laudan, 1983) and ontology, and much more on the ethics and governance of science (Benessia et al., 2016). The key aspects of post-normal methodology- participation, humility and transparency, emerge not just from the nature of the objects being studied, but the social structures that create and use knowledge. The "crisis of science" can be seen far beyond areas where flawed social ontologies could be to blame, including in medicine and toxicology (Ioannidis, 2005). Declining public trust in science comes from industry capture, perverse incentives to "publish or perish" and from policy-makers who demand "hard evidence" to justify decisions even when science cannot possibly provide it. Quantitative modelling has severe limitations in guiding decision-making, even in domains where these models are clearly an appropriate theoretical tool, such as costal erosion (Pilkey & Pilkey-Jarvis, 2009). Inherent uncertainty gives little firm guidance in choosing scientific methods, but its implications for how science is interpreted, synthesized, used and governed are much stronger.

The place of so-called "neoclassical" economics in post-normal science is thus unclear. While "the social cost of carbon" may be ridiculed as an absurdity (S. O. Funtowicz & Ravetz, 1994), and cost-benefit analyses are rejected, there are numerous aspects that may be appropriate. For instance, the basic formal models of economics may be valid as "qualitative models" (Pilkey-Jarvis & Pilkey, 2008), weak heuristics for capturing important dimensions of socio-economic phenomena (Colander, 2016), or means of identifying likely unintended consequences of policy (Popper, 2014). This limited use of neoclassical theory as one component of EE is epitomized by Daly and Farley (2014), among others. Likewise, using econometric methods to estimate harms from pollution (Bishop et al., 2018; Heissel et al., 2019; Kahn & Li, 2019) and benefits of environmental conservation (Golden et al., 2011; Herrera et al., 2017) appears to be very useful, and decidedly within the economics mainstream, though methodologically fraught.

There is a long tradition in the field of economics of scholars skeptical that even the most rigorous economic science can be directly translated into robust policy recommendations. For instance, both the elder and younger Keynes described making policy recommendations on the basis of economic science as a form of "art" (J. M. Keynes, 1938; J. N. Keynes, 1890). Hayek more forcefully argued that expertise in economic science may not translate to policy expertise (1974) and Colander states flatly that "Economic Theory has Nothing to Say about Policy" (2015). Indeed, one of the primary goals of early neoclassical economics was to prove that policy recommendations cannot flow seamlessly from economic science (Porter, 1996).

While the various goals discussed here are all at times referred to as

[4] With regards to policy prescriptions, Hagens writes "we can increasingly be confident of what won't happen" (p. 163) with regards to policy changes that could stave off collapse.

Table 1
Summary of Key Issues in Interdisciplinarity and Transdisciplinarity in Ecological Economics.

	Integrative Interdisciplinarity:	Action-Oriented Transdisciplinarity
Key Questions:	-How are the domains of natural and social sciences delineated on a human-dominated planet? Can they be? -What does it mean for social sciences to be "consistent with" natural sciences? What does it mean for them to be "overly reductionist" to the natural sciences? -What makes social sciences "scientific"?	-Whose formulations of problems and solutions are privileged? -If "some models are useful" then to whom are our models useful? -What does genuine, participatory democracy look like for problems with complex scientific causality and impacts? (e.g. climate change, environmental toxicity).
Major Tension:	-Risk of simplification/dogmatism vs inconsistency.	-The risk of engaged science becoming top-down and "technocratic" vs a science which stays "above" politics and rejects its transformative potential.

"interdisciplinarity", there is no a priori reason to believe that the best intellectual environment for each of these might be the same. Indeed, enormous tensions exist between these prominent conceptions of interdisciplinarity. Jantsch's (1970) seminal definition of transdisciplinarity emphasized top-down control of the activities of "lower-level" disciplines (e.g. physical sciences, behavioral sciences) by "higher-level" ones (economics, ethics) while much interdisciplinary thinking in Ecological Economics argues for reconsidering the foundations of higher-level disciplines through bottom-up reform (Brown & Erickson, 2014; Georgescu-Roegen, 1971; Melgar-Melgar & Hall, 2020). The academic knowledge system is a complex one, and complex systems are characterized by both top-down and bottom-up controls, but arguments for either will largely be incommensurable. Spash (2012) has been far more detailed than other Ecological Economists in articulating both top-down (ethical, ontological and epistemological) and bottom-up (bio-physical) principles for guiding an interdisciplinary Ecological Economics.

When Ecological Economists argue for a "paradigm shift" in economic thinking (Gowdy & Erickson, 2005; Spash, 2012), they are arguing that economists should trade one set of intellectual blinders for another; this is inherent in the meaning(s) given to the word by Kuhn (1970). The intellectual environment for a new paradigm in economics requires a narrowing and disciplining of thought and methods; "eclectic pluralism… is the antithesis of creating knowledge (Spash, 2020)." Such a paradigm shift would involve greater consensus on objects of study, methods, theory and terminology; it would give Ecological Economics most of the trappings of a scientific discipline.

Reforming or revolutionizing economic science, however, will not deterministically result in better policy or decision-making. Intellectual models of the world, no matter how good, are complements to, not substitutes for, judgement, deliberation and well-designed institutions in decision-making. Further, the degree of narrowing and consistency required to develop a robust, well-criticized body of knowledge will always be more than is healthy for policy-making; in the words of Saltelli and Giampietro, "There is nothing wrong in using blinders in the quest for theoretical progress. The issue is when the same tool is used to prescribe policy, expediently neglecting the blinding stage." (Saltelli & Giampietro, 2016, p. 13).

The quests for a better economic science, more in harmony with ecology and the other social sciences, and for better means to connect science and society are both interconnected and incommensurable. The name "Ecological Economics" has become overloaded with meanings, as it describes multiple perspectives on each of these questions. This contributes to the weakness of the identity and reputational authority of Ecological Economics (Røpke, 2004, 2005). In the first issue of this journal, Proops (1989, p. 60) stated that "Ecological economics studies how ecosystems and economic activity interrelate "a definition that "runs the risk of being so general that it includes almost all scientific and social scientific disciplines (ibid)." Given the breadth of the definition, it is unsurprising that most scholars who do work related to EE do not identify with the field.

4. Conclusion: The next 30 years

Ecological Economics exemplifies the ambiguity in supra-disciplinary academic endeavors. It is conceived of as a forum for novel ideas, a nursery for new research programs, and a movement to improve economic science and/or social decision-making, either by reform or revolution. This profusion of meanings seems to over-burden a single name and an international society of just over one thousand members. Lacking consensus, the field and journal has defaulted to a place of brainstorming and debate, as evidenced by numerous contributions disputing methodology and ideology This process has been highly generative, as numerous ideas have emerged to much broader relevance, but the successes of these ideas have not brought greater institutional power to the Ecological Economics community. A spirit of pluralism demands that we acknowledge the value that all these endeavors may have, but trying to do everything at once, within one tent, is unlikely to build institutional power for our research community.

Given that Ecological Economics remains a community of pluralistic debate, we would do well to focus debate on issues of inter-disciplinary integration, and the interface of science and society. The community appears to hold a wide range of views on these subjects (Dube, 2020), and these disagreements are often overlooked or conflated with one another. Ecological Economics remains united by shared belief that a healthy biosphere is essential to human well-being and that current scientific and policy approaches must be reformed, but by little else.

4.1. The next 30 years

The success of Ecological Economics over the next 30 years should be judged based on the impacts made by its ideas on the pressing challenges of the mid-21st century. Pluralism in facing these challenges is essential; these problems are unprecedented in their scope, and no one knows which approaches will ultimately be successful.

Ecological Economists can respect differences in intellectual theories and theories of change. At the same time, we should also organize spaces with like-minded scholars to ensure that academic research and education can be undertaken without constant re-litigation of basic assumptions. Multiple "schools" of Ecological Economics are already emerging. This development can be positive; it will allow researchers to more deeply explore their chosen frameworks within their limitations. The umbrella of Ecological Economics can continue to allow for robust criticism and exchange between these efforts.

Some ideas which may prove fruitful in making transformational impacts include:

Train Ecological Economists to Replace Mainstream Economists in Bureaucracies:

Governments, NGOs and multi-lateral organizations hire an enormous number of economists, often not due to their understanding of economic theories, but simply their skills in working with quantitative data. PhD programs which teach both an Ecological Economic pre-analytic vision and theories, but also quantitative social science

methods could produce Ecological Economists who could "replace" mainstream economists in these organizations. This could allow an EE perspective into these organizations in a progressive manner.

Focus on Policy Development:

Ecological Economics practitioners and perspectives will gain influence in government to the extent that they can provide solid, actionable policy advice. Working with municipal and regional governments to implement achievable policy changes can build the reputations of scholars and the field as a whole and build capacity to make more transformative changes.

Work to Revolutionize Economics Education- From the Inside or the Outside:

Introductory undergraduate economics courses are the only formal education in economics for millions of people. Introductory Economics courses are often far more dogmatic than the actual state of scholarship within the field (Colander, 2016). Ecological Economists should continue to work on reformist curricula which examine mainstream economic concepts within a broader ecological and social framework (e.g. Commn & Stagl (2005), Daly and Farley (2011)). Other Ecological Economists should continue to work towards more transformative pedagogies (Røpke, I., 2020, Vargas Rocncio, et al. 2019).

Keep Open Communication Between Radicals and Reformers:

Scholars working to bring Ecological Economics into policy-making will inevitably make compromises in their work. To do this work responsibly scholars must invite incisive critiques of their efforts from other scholars using different frameworks and from the public at large. While the opposing factions within EE may make the field look like a mess to some, there are substantial strengths to maintaining lines of communication between those working within current systems and those working outside of them.

Cultivate Relationships with Social Movements:

Building relationships with movements for social and environmental justice allows EE scholars and institutes to take in fresh ideas and see their advice critiqued and implemented. Over the long term, these relationships can allow scholars to give trusted advice.

Ecological Economics seeks to understand and alter complex socio-ecological systems. Like these systems themselves, the process of building knowledge about them is filled with novelties. Maintaining a diversity of thought models and interconnections between these models makes our community more resilient and more adaptive, if also less efficient. The strength in this diversity is also an argument for greater articulation of different communities and sub-approaches within the field; it is only by articulating these differences that meaningful dialogue, criticism and cross-pollination can occur across them. Ecological Economists should both embrace the usefulness of pluralism while being cognizant of the different goals it is being put to.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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