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Science in the Trading Zone: Interdisciplinarity and the 'Environment'

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Abstract

Interdisciplinarity continues to be a focus and method for complex social and environmental challenges. This paper explores how the School of Environmental Sciences (ENV) at the University of East Anglia (UEA) which was founded through the idea of scientific interdisciplinarity operated in practice to create new knowledge about a new object of concern, the 'environment'. Using the 'trading zone' concept, the social and epistemic processes behind making scientific interdisciplinarity a material and institutional reality are uncovered, and to what extent interdisciplinary knowledge was *actually* produced. This paper concludes that interdisciplinary processes can be effective in dealing with complex challenges but often rely on the institutional and social dynamics of the researchers involved. Historicising interdisciplinarity in knowledge-making settings can go some way in supporting new interdisciplinary endeavours associated with environmental and climate research.

INTERDISCIPLINARITY AND THE 'ENVIRONMENT' TODAY

Interdisciplinarity is often seen as the solution or medium in which to effectively address complex challenges of climate and environmental change. Multiple scholars have recognised interdisciplinarity as the most appropriate research framework or practice to address the multi-dimensional and ever-increasing complexity of the social and environmental sciences (Bammer, 2017; Hein et al., 2018; Nisbet et al., 2010), as it brings diverse experts together to solve complex challenges. Consequently, interdisciplinarity has also become a key issue for governments, funding agencies and researchers (Barry & Born, 2013); with many researchers advocating increased cross-disciplinary collaboration (Honeybun-Arnolda and Obermeister, 2019), exploring new forms of interdisciplinary science and governance (Biermann et al., 2010) or uncovering the ecologies of sense-making, world-making and co-productions of knowledge and practice (Honeybun-Arnolda, 2022; Latour & Weibel, 2020; Tsing, 2015). Exploring historical

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moments of interdisciplinarity: under what contexts it emerged, for what purposes and whether or not cohesion and practice were achieved is particularly timely, as interdisciplinarity (and transdisciplinarity) training for PhDs and researchers has been lauded, once again, as a means in which to know and understand to the complex challenges of the 21st century (Nature Editorial, 2023).

The environment and climate have been framed in the 21st century as objects of knowledge that cross-cut traditional disciplinary forms like physics, biology, chemistry, social science, arts and humanities and even necessitate the need for new disciplines) in which to make sense of, or know and understand, the changing world around us. Further, changing environmental concerns throughout history have required input from a range of diverse actors like farmers, foresters, water body experts, health advocates, and so on (Sheail, 2002; Thomas, 1983) to overcome and manage areas of interest – even before formalised structures of expertise and knowledge were recognised. Notwithstanding, disciplinary the act of 'disciplining' knowledge unfolded in the 19th century, as universities began to institutionalise knowledge-making and learning through organised silos and approaches (Golinski, 1998; Kohler, 1981; Schaffer, 2013; Weingart & Stehr, 2000). Since forms of knowledge have been organised into disciplinary fields have the potential and possibility of crossing boundaries been apparent and utilised to advance knowledge (Renn, 2020; Schaffer, 2013). However, continually interdisciplinarity appears as a remedy for the many scientific and environmental challenges of the present, most prominently demonstrated recently through action and research coalescing around the United Nations Sustainable Development Goals (Keynejad et al., 2021) and the Anthropocene, both practically (Lundershausen, 2018) and theoretically (Renn, 2020).

Yet, as this paper sets out to demonstrate, interdisciplinarity and interdisciplinary approaches are not novel, nor are they specific to the demands and challenges of the 21st Century and it is not pre-given that interdisciplinary collaboration will be productive or generative. Rather, interdisciplinarity is both a social and epistemic process that is contingent on the context, spaces and actors involved and is a critical feature of the evolution of knowledge (Renn, 2020). The present emphasis on interdisciplinarity, as the means by which to explore and solve complex challenges, obscures the material and epistemic challenges and institutional contexts involved in producing coherent and unified interdisciplinary knowledge. As a result, this paper historicises the emergence of interdisciplinary science to understand the 'environment', at a university in Britain (UEA) to resituate claims of the need for interdisciplinarity today and show how, in the 1960s and 1970s, interdisciplinarity was a process of difficult epistemic and ontological negotiation to produce knowledge and was lauded as the solution to problems focused on the 'environment', like that of today. This was not inevitable but rather a product of specific political imaginaries, institutional choices, and visions of desirable futures. I also aim to encourage a deeper understanding of university interdisciplinarity helping advocates of interdisciplinary practice to think more critically about the conditions that make interdisciplinary research possible in the present. Interdisciplinarity may appear as a self-evident and important approach in the production of scientific knowledge but it is not an easy feat. Robust and 'new' knowledge is not pre-given and as I reveal in the passages below is often largely contingent on the institutional capacity, institutional epistemology and educational vision to facilitate inter/multidisciplinary collaboration.

To do so, this paper draws from archival material and oral histories to explore the social processes and practices of the researchers involved to demonstrate the historical realities of interdisciplinary research using the first decade of the School of Environmental Sciences (ENV) at the University of East Anglia existence (1967-1977), as the focus of study. Specifically, to explore the messy realities and materialities of how new attempts to produce interdisciplinary science in a new university department played out in practice, I use Peter Galison's (1997) 'trading zone' concept to explore how disparate and cognate disciplines came together through local coordination efforts in an attempt to share tools, methods and ideas to create a new branch of science focused on the 'environment'.

This paper begins by first unpacking the contexts surrounding ENVs formation and recruitment noting how the first Dean was perceived to be critical to realising ENVs goals as an interdisciplinary department. Next, the founding years are explored detailing the backgrounds, research practices and publishing patterns of the staff employed by ENV in the beginning. I then explore the apparent dichotomy between social and natural sciences exploring the

epistemological and ontological tensions that hindered truly interdisciplinary work in ENV before drawing conclusions for the future social studies and practices of scientific interdisciplinarity.

ENV AS A TRADING ZONE

Interdisciplinarity was proposed by Solly Zuckerman, Britain's first Chief Scientific Adviser, as a key model for the new 'environmental sciences School at the University of East Anglia (ENV) that was founded in 1967. At the time, interdisciplinary working was perceived by science advisors, policymakers and civil servants as the means to revitalise and transform the landscape of knowledge-making in Britain. UEA and ENV emerged as a material consequence of Britain's technocratic vision of society in which new scientific and technological expertise was to be at the forefront of a postwar reconstruction and emerging global community. UEA (and other new universities of the 1960s) were seen as an institutional experiment that aimed to deal with the perceived stagnation of higher education and scientific training in the more traditional universities e.g., Oxford and Cambridge (Agar, 2020; Honeybun-Arnolda, forthcoming). ENV was to make knowledge about the newly emerging 'environment' through interdisciplinary research and was to teach its new students through an interdisciplinary curriculum.

Indeed, interdisciplinarity has a long intellectual history and much discussion, that goes beyond the scope of this paper, has ensued over how different forms of expertise collaborate, through what aims, with what reasons, and to what extent (see Barry & Born, 2013; Klein, 1996; Kohler, 1981; Sugimoto & Weingart, 2015). Peter Galison (1997) posited that scientific disciplines are heterogeneous, and 'disunified', and must learn or implement methods and techniques to collaborate and reconcile ontological and epistemological differences in practice and procedure. Scientists operate in a 'trading zone', a material or relational space to reconcile epistemic and ontological differences and attempt through local coordination to generate new knowledge, ideas, practices or methods. This can often happen through varying methods of concept sharing, instrument building, experimenting, knowledge exchange and theorising as disparate or cognate traditions antagonise, resist or support and collaborate to co-construct new ideas, vision and knowledge.

To think of ENV as a trading zone, the university department and epistemic space in which new interdisciplinary knowledge could be produced is an important conceptual move in unpacking the interacting role of the different cultures of knowledge-making which emerged in and shaped the early years of ENV and more broadly, the environmental sciences. A trading zone, I argue, need not be a formalised space of scientific or academic work but rather can be multiple spaces in which diverse researchers with distinct disciplinary perspectives come together and interact and produce shared visions and understandings of knowledge exchange. ENV, in the earliest years (and remains today) a space in which researchers and scientists with diverse disciplinary backgrounds operate, interact and produce knowledge under a shared institutional vision of the 'environmental sciences'. This was the case from the outset when Solly Zuckerman, as part of UEA's academic planning board, suggested that UEA should,

> … do something absolutely new and fresh in science, I am wondering whether Norwich could not embark in its faculty of Science, on a Division of Environmental Sciences – meteorology, oceanography, geology, conservation etc. If it were, I am quite certain that nobody would ever be able to say that scientists were trained in a narrow way … Conservation would lead to the social sciences, population studies etc. and so over into the preoccupations of at any rate one sector of those who teach the humanities.[1]

The 'environmental sciences' in ENV were proposed to understand the emerging 'environment' across both the physical and social sciences overlapping into the humanities. The School was intended to be a place in which

scientists and students could be trained to understand the 'environment' as a whole – understanding the systemic nature of physical earth systems and the mutual interactions between society and the environment. Yet, as ambitious as this was. The beginning search for a dean excised the input of social sciences and the humanities.

THE SEARCH FOR A DEAN

The first step to bringing the interdisciplinary vision to life was identifying a new dean; one that was willing and able to implement Zuckerman's vision of ENV. Zuckerman himself was too preoccupied with other professional commitments, namely being the UK CSA.[2] Nonetheless, his vision remained the lodestar that guided the work of the ENV Working Party (ENV WP); a group of academics designated to deal with the early orchestration of the School), which began the search for a dean by first drafting an advert to be published in January 1966, stating:

> The University proposes to establish a School of Environmental Sciences with interest in the subjects of Geography, Geology, Geophysics, Land Use, Atmospheric Science and Oceanography. The Dean will be the holder of the first chair in one of the subjects and in addition will be responsible for the organisation and administration of the School and for the general development of the group of subjects within the School.[3]

The advert was published in national newspapers and academic magazines and illuminated ENV's initial commitment to scientific interdisciplinarity in working and teaching, albeit not mentioning the humanities or social sciences in the proposal whilst also adding geography to the mix.[4]

The ad also revealed ENV's ambitions to become the key place of 'environmental' study through the growth it intended, going on to state that "it is intended that the number of undergraduates in the School should increase year by year from 30 in 1967/8 to 240 in 1972/3". Not only was ENV recruiting for a brand new department, ENV was also in competition with existing universities or degree programmes and wanted to ensure institutional longevity. It was proposed by the administrators that ENV's staff, once hired, was to focus efforts to recruit students who would usually apply to geography, geology and geophysics degrees, with a potential pool of candidates being estimated at 1403 students.[5] As this was a new subject, there no were A-level students explicitly studying environmental science or studies. The new dean was to develop a course and staff body that could attract both human and physical geographers in pursuing a broad 'environmental sciences'.

Once the advert was posted publicly in the media and circulated through the ENV WP's academic networks, there was considerable interest from applicants. Many were interested in what they viewed as the freedom to pursue their scientific ideas under the umbrella of ENV but were rejected due to their ambitions to move beyond or alter the broad vision laid out by Zuckerman.

Geoffrey Eglinton, a chemist at Glasgow, wanted to pursue an interdisciplinary field of organic geochemistry that would have benefited from being in close quarters with "geologists, soil scientists, limnologists, oceanographers and palaeobotanists"[6] Conversely, the human geographer Andrew T.A. Learmonth wanted to pursue a greater mix between social sciences and the earth sciences.[7] There was also an interesting suggestion from the Cambridge geologist Walter Brian Harland to "discard most of the words like 'oceanography', 'geology', 'geophysics' and so on…" in favour of studying the environment as more loosely, 'solids', 'fluids' and 'biological systems'.[8] Hubert Lamb of the UK Meteorological Office offered himself for the position before later arriving at ENV as Director of the Climatic Research Unit.[9] These and many other applications sparked interest and debate among the members of the ENV WP but were disregarded broadly on the basis that the ideas had moved too far away from the original grouping of disciplines proposed by Zuckerman and set out in the advert, or because applicants did not have enough of a strong background within the constitutive disciplines of the advert to guide

ENV in the crucial early years. The key to the success and longevity of ENV and the 'environmental sciences' School, in the first instance, was thought to be student numbers and, subsequently, the future careers of ENV graduates. If student numbers were to come from both human and physical geography, then it was thought by the ENV WP that ENV needed a dean who could traverse both arts and science and encourage a new interdisciplinary culture in ENV.

TOWARD A NEW INTER/DISCIPLINE? ENV IN THE FOUNDING YEARS

Keith Clayton, a geomorphologist, previously based at the London School of Economics was hired in 1967, a year before students were welcomed to set foot in the lecture halls of ENV, to prepare the acquisition of books, technical equipment, and the hiring of staff. Brian Funnell, a geologist hired as second in command to support the combination of geography and geology, was to start at the same time as the students. Clayton had the important task of recruiting the founding staff despite being continually doubted during his own recruitment process. With geography and geology being decided by the ENV WP as central to the successful recruitment and enrolment of students, Clayton had hired staff who were all geographers or geologists in first- or advanced-degree training.[10] This eclectic mix of predominantly earth and physical science expertise was the staff roster tasked with developing the original undergraduate programme which was oversubscribed by the time it was up and running in the first year.[11] The original decision to cut social sciences from the proposal was notable as ENV began to become skewed towards physical understandings of the 'environment'.

Notably, the early staff were to work together to teach basic (and overlapping) introductory courses of earth sciences, geography and ecology before students then went on to choose module options. The following year, after a second round of hiring the staff became more diverse, including Fred Vine (a geophysicist and geologist – to join in 1970), Peter Liss an ocean chemist postdoctoral researcher from Southampton and David Dent, a soil scientist. Consequently, ENV and Clayton had begun to construct a space that included multiple strands of science working toward producing a new and interdisciplinary 'environmental sciences' curriculum and field that had become heavily aligned to the natural and physical sciences.

Critically, there were particular ways of conceptualising the 'environment' for the different physical science disciplines emerging even in the earliest years of ENVs founding when the 'environment' as an object of scientific concern was finding stability. The ontological differences between the different disciplines involved (re)shaped different practices, guiding values, lines of enquiry and methods of knowledge-making. For the natural and earth scientists – the physical, chemical and biological aspects of the environment were key (Oreskes & Doel, 2002).

The interaction between physical earth systems – like oceans, atmospheres, soils, and climate – were becoming more deeply understood in the post-war period (Doel, 2003). This, in turn, led to the emergence of new instruments and techniques that supported the production of new physical and numerical knowledge about the earth began that recognised these earth systems as interconnected 'environments' and susceptible to alteration from human processes (Oreskes & Doel, 2002; Warde et al., 2018). A shared ontology was critical for an interdisciplinary epistemology and institutional culture to match.

In ENV, the 'environment' as an object for thought emerged through multiple framings resulting from the range of disciplines being employed as founding staff. ENV is one of the earliest examples of the institutionalisation of multiple research cultures sharing and collaborating long-term, in a host space or 'trading zone', the university (Galison, 1997; Knorr-Cetina, 1999) but how did it play out in practice? Examining the publication history of ENV reveals the patterning and authorship of the early published research. By reviewing Web of Science and Scopus databases from the years 1967-1974, scraping work from all those in ENV at the time, combined with a broad search on *Google Scholar*, the research and publishing activities of the staff of ENV in the earliest years to get a sense of how visions of the interdisciplinary 'environmental sciences' played out in practice in the ENV trading zone.

Initially, roughly over half of publications found in the databases between 1968-1974 were sole-authored, with most of the work published in specialist disciplinary fields related to the earth or atmospheric sciences or oceanography. There were several papers published in the multi-disciplinary science journal *Nature*.[12] From the more human-orientated geographers (who joined the staff roster a few years after the natural scientists), work was published in geography or area studies journals like *Regional Studies* or *Agricultural Geography*. There were co-authored papers but often with same discipline graduate students or others in similar departments; for instance, the geologists in ENV would collaborate with other geology departments. ENV claimed to be a space of inter-disciplinarity but evidence through formal publications was minimal. Several researchers (geologists, chemists, geographers, geophysicists), however, were mentioned in the acknowledgements sections of early research publications as crucial components in engaging discussions and idea development.

Anecdotally, this appeared to not mirror how those within the institution recalled interdisciplinary working in ENV. As soil scientist David Dent recalls, he enjoyed working with a geologist on field expeditions:

> …we crawled on our bellies, deep under glaciers. Washed by ice cold water. To find out how they work in winter, as opposed to just in summer, so we did that in midwinter as well. And that was… we went several times. So, [we] made several trips to [Iceland]. It was always great fun. …[13]

These collaborations culminated in a few publications - as ENV was stabilising as a department - (Boulton & Dent, 1974; Boulton et al., 1974), but critically also shaped how each other thought about science, 'environments', and their work within. For instance, Boulton, a geologist, interested in glacial environments and glacial processes, was collaborating with Dent, a soil scientist, to ascertain the variable origins of glacial till - what were once thought to be soils formed from glacial retreat could also be subglacial and so this interdisciplinary collaboration was changing the ways stratigraphy and sedimentology in glacial regions may be understood (Boulton & Dent, 1974). The core methods of observation and description in the field meant that both disciplines could easily share, collaborate and build on one another's expertise to generate new ways of understanding earthly processes – like soil formation in glacial environments and how to measure environmental change. The oceans-atmosphere interaction further illustrates this point.

The research work of environmental chemist Peter Liss was almost explicitly interdisciplinary from the outset. Liss embarked on an interdisciplinary research and teaching programme studying chemistry entangled with oceans and atmospheres and made meaningful collaborations inside and out of ENV. Liss recounted that ENV's multi-disciplinary arrangements and institutional capacity were crucial for this,

> I've got to say that my research was quite interdisciplinary. I mean, I was studying the ocean, the atmosphere and how they interact. That's… that's quite interdisciplinary in the sense that in many universities, not UEA, fortunately, but in many universities, there are separate departments of meteorology and oceanography.[14]

Liss also recalled being able to attend an interdisciplinary and international conference on Marine Geochemistry early on in his ENV career, funded by ENV, that enabled him to make lifelong connections through international collaboration and a fledgling interest in air-sea gas exchanges. Moreover, Liss notes that the freedom from ENV administrators emphasised that this was a new inter/discipline carving out its own space and was empowered to explore the emerging links between cognate disciplines,

> I think we were given, well, effectively carte blanche to develop whatever field we wanted. I mean, within resources, either [that] the University and School had or resources we could win, you know, from some research council or whoever. So, I think we had an - I mean, we were encouraged to think

> broadly and on a broad canvas… [and] there was a lot of freedom … and a lot of emphasis on doing whatever you think needs to be done in this, this totally new subject area.[15]

Oceans-atmosphere work was more conducive to interdisciplinary working and knowledge-production than an ecologist and sedimentologist working together, for instance. Oceans and atmospheres are both understood to be fluid chemical systems and reservoirs (Liss, 1975; Liss & Slater, 1974). Ontologically, oceanographers and meteorologists viewed their objects of enquiry (atmospheres and oceans) similarly and shared methodological techniques and practices. A shift from description and observation to applying physical principles, standardised methods and numerical techniques came from physicist Wilhelm Bjerknes, becoming the dominant practice in meteorology as future weather-system behaviour could now be predicted through mathematics-based calculations (Ellingsen et al., 2018; Oreskes & Doel, 2002). This overspilled into oceanography as a previously inaccessible object of concern, now investigable through physical methods, instruments and analysis, and the field almost mirrored meteorology in the post-war period (Hendershott, 1980). For scientists like Liss, it seemed apparent to investigate the possibility of interaction due to the shared physical and numerical approaches, instruments and the ease at data sets. Liss and colleagues in ENV sought after existing data by writing to other scientists. They collected a range of data on air-sea-gas interactions, which was essentially "a data assimilation exercise" in discerning the interactions of air-sea-gases and the interactive role of oceans and atmosphere in global chemical cycles (Liss & Slater, 1974). This process of sharing similar means of observation and data collection made unifying distinct branches of physical science easier for scientists in the ENV trading zone to coordinate and interact fruitfully to develop new insights and understanding – both in the field and in the department.

Nonetheless, there were also recollections, from Dent, concerning informal collaboration through conversations concerning teaching and research projects with a range of individuals in ENV beyond their expertise, noting specifically conversations with an ecologist, a river hydrologist and an environmental chemist concerning possible teaching and curriculum collaborations and fieldwork. These informal interactions demonstrate the seeming significance of scientists or researchers with diverse specialisations being in close contact with one another to share ideas, and views, collaborate on papers or courses, and ultimately shape new interdisciplinary thinking and cultures of knowledge-making. For example, numerous staff and research students mentioned the importance of the coffee room as a space of informal knowledge exchange and interaction (cf. Livingstone, 2003):

> … we all regularly met in the coffee room and had lunch together and exchanged ideas, and people would share what they were working on.[16]

> …when I saw for example [another member of staff] with a cup of coffee, I knew alright, I've can interrupt [them] now. And dearly did and coffee [breaks] often lasted for hours while we talked through … science. Marvellous.[17]

The spatial proximity of researchers also seems to be key and the 'trading zone' can be opened out to include the generative potential of the informal and conversational setting in which science develops, advances and ideas are generated. Alongside, being situated in an institutional culture that promotes a distinct institutional epistemology (Borie et al., 2021) of autonomy and freedom to explore and be creative cultivated a sense of physical closeness in ENV. For most in the ENV trading zone, disparate experts were able to come together in informal spaces of interaction and rest, like the coffee room or between offices, to 'talk science', discuss research plans, and opportunities and bounce ideas off one another for the teaching curriculum. Different visions of what the 'environment' was from different scientific disciplines meant that there was much worth discussing with a chemist about how best to understand the environmental chemistry of soil or asking a climatologist to demonstrate on a meteorology course. Crucially then the social aspects of researchers involved were key to generating conversation and ideas this

also meant that the degree programme was 'interdisciplinary' and promoted interdisciplinary knowledge and approaches in ENV graduates, even if the earliest actual research produced and published was not.

A DICHOTOMY BETWEEN THE NATURAL AND SOCIAL SCIENCES IN ENV

Despite some of the more successful interdisciplinary collaborations in ENV, the uneven composition of natural and social science in the earliest years of ENV is notable, given Zuckerman's proposal in 1960 that highlighted the need for natural scientists, social scientists and humanities to work together in a broad study of the 'environment'. It is also noteworthy, given the time of ENVs formation, that the integration of the humanities and the sciences or the 'two cultures' (Snow, 1959) was not taken more seriously – in an institution that was founded to produce new and innovative knowledge. Social science and humanities-based scholarly works were slowly emerging in the broader research landscape at the time. During the 1970s, the environmental movement in the West proliferated, as conservationist ideas from Carson, Vogt, and Osborne Jr gained traction and researchers from social and political sciences, like Bob Kates, Bill Clark, and Tim O'Riordan began to become more involved to understand how social processes and environmental change interacted.

Notably, O'Riordan joined ENV in the mid 1970s having published on the role geographers can play in understanding the social impacts of environmental change and environmental knowledge making (O'Riordan, 1970) and then, whilst in ENV, publishing on the inadequacy of existing social approaches to the 'environmental sciences' (O'Riordan, 1973). There were also several human geographers – John Tarrant, David Hauser, John Barkham and Malcolm Mosely who had joined ENV around the same time as O'Riordan. Yet there was epistemic tension between the natural or realist approaches to science through different problematisations of 'environment'. As Fred Vine stated,

> … there is this social geography side [of the 'environmental sciences'] which obviously separates off and you couldn't really include that – although they call it social science and they would like to think it is a science and, in some sense, it is a science, but it's not a hard science [laughs] in the way that other sciences are…[18]

And another mentions that,

> …for the majority of ENV, interdisciplinarity meant bringing physical disciplinary sciences together, chemical sciences together. So, Met and Oceans was seen as interdisciplinary rather than Met, Oceans and political sciences and sociologists.[19]

The epistemic tension between physical and social scientists or human geographers and everyone else in ENV points to boundary issues that challenge and obscure truly interdisciplinary research (Gieryn, 1983). If there is antagonism or conflict between disparate disciplines in the trading zone, an unwillingness to share, interact or be shaped by others then the research will remain only partially interdisciplinarity. As mentioned above, the social characteristics and institutional culture are key to generating collaboration, unification, and coordination of research in the trading zone and this must be embedded throughout. Barry and Born (2013) detail this in the present day as 'agnostic-antagonistic' models of interdisciplinary practice that directly position disparate disciplines with contrasting epistemologies and ontologies to find common ground and produce truly interdisciplinary and novel insights. This was not present in ENV and the social scientists and human geographers did not, for the most part, experience positive reception and collaboration from their natural scientist counterparts.

However, this division of natural and social science perspectives leads to an interesting sociological and philosophical question regarding the constitution and characteristics of science about the 'environment' and as a tool for

ruling institutions, both conceived by Zuckerman and others more broadly. The internationalisation of science that boomed during the post-war and Cold War period propelled interdisciplinary and collaborative work in the earth and 'environmental sciences' (Doel, 2003) but Zuckerman emphasised diverse understandings of the 'environment' as key aspects of the 'environmental sciences' normative and epistemic importance, rather than aiming for a unified 'environmental science'. Zuckerman also favoured, as discussed elsewhere (Honeybun-Arnolda, forthcoming), sciences that solved social problems. The growing dominance of scientific authority, expert organisations and the transmutability of natural science methods, theories, instruments and data meant that circulation and scaling were seemingly easier in a world that was becoming more global, standardised and increasingly focused on mapping and predicting forms of environmental change.[20] Qualitative or interpretive frameworks, in a technocratic society, may not be seen as easily circulated, or mobilised to solve material or epistemic gaps like that of the physical or natural sciences. This tension between social and natural sciences underscores the absence of social scientists and human geographers in the nascent 'environmental sciences' in ENV, despite many of the early environmental challenges in Britain being resolutely social e.g. agricultural challenges and food security, toxicology and so on.

It can be seen then that the ENV trading zone restricted the formation of different types of interdisciplinary cultures or models of research. This was made apparent by the boundary work and competing visions of what the 'environment' is and how it should be known, by the natural and earth scientists. This division was further exacerbated by the lack of financial support or rewarding professional incentives from ENV and outside organisations, like the Natural Environment Research Council (NERC), to prioritise these kinds of work in the 1970s and 1980s.[21] For instance,

> It's a lot easier to publish if you publish in a … chopped up little thing where you've got a journal already waiting for you. It's … much more difficult to get to work in something you know damn all about. And also to get published In the kind of journals that have always had some kudos, which are the chopped-up specialist things. And you can see it happen. So those who went that way … all became Professor somewhere else.[22]

And another noted the dissuading factors for multi-/interdisciplinary research projects,

> I've suddenly remembered that you only got promotion if you had gotten the grant, and all the papers that are published just have your name on, certainly you [as] first name and probably one of your research staff as second name. But you didn't get any credit if there were five people on a topic that only could have been written up with the five people's involvement. There was no credit for that.[23]

Consequently, these institutional factors meant there was little appetite or incentive in ENV for interactive and challenging connections to be made. In the sociology of inter/disciplines and specialisations, rewarding incentives like professional development are key in cementing and embedding new specialisations within or beyond disciplinary formations. Early work in the sociology of specialisms argued that new specialisms emerged from a demand for effective research and as new scholars looked to create their own epistemic space to advance their professional careers (Ben-David & Collins, 1966; Price, 1963). For ENV, this is partly relevant as several of the early staff noted the allure of epistemic freedom given by ENV:

> …we were encouraged to think broadly and on a broad canvas… there was a lot of freedom … and a lot of emphasis on doing whatever you think needs to be done in this totally new subject area.[24]

> …pretty much everything was started from scratch with generally the Zuckerman idea - as interpreted by Keith [Clayton], to produce this broad, but deep environmental sciences syllabus, which we invented from the top of our heads … and that itself is very exciting. Especially if you're young.[25]

Consequently, as a new university, UEA was encouraged to create new interdisciplinary research programmes that drew on existing and new connections between existing disciplines and did so through enabling epistemic freedom but alongside the wider higher education landscape, failed to incentivise collaborative interdisciplinary research across the physical and social sciences and so competitions within ENV to become champions of an interdisciplinary science were not forthcoming.

Nonetheless, despite the original aims of the cohesive and interdisciplinary 'environmental sciences', disciplinary silos were still prominent for some years after ENV's founding. Additionally, the interviewees here have mostly been given pseudonyms under 'environmental scientist' but most would not define themselves as such and may rather identify themselves according to their specific constitutive discipline e.g. soil science, oceanography, sociology, economic geography, conservation biologist and so on.[26] Despite the wider challenges of academic reward structures, it was believed that ENV could have done more in the early years, it was noted, to break down these existing divisions, as originally intended,

> ENV has always been primarily a multidisciplinary rather than an interdisciplinary institution. I never really felt that interdisciplinary work was actively encouraged; there wasn't a strong culture of interdisciplinary collaboration across the department as a whole. Interdisciplinarity may have been the ENV ethos, but it could have been promoted more assiduously.[27]

It was not until towards the end of the decade that formalised and institutionalised interdisciplinary work between natural and social sciences was embedded in the School's fabric, with the creation of the Centre for Social and Economic Research on the Global Environment (CSERGE) in the early 1990s and Tyndall Centre for Climate Change Research in the early 2000s,[28] when the School was more institutionally stable with more journals and outlets to publish in.[29] From the outset, these were intended to be interdisciplinary centres of environmental research. Still, even these underscored particular ways of understanding the 'environment', how knowledge should be made, and for what purpose. Specifically, CSERGE emerged and secured funding from the ESRC when evidence-based decision-making had been increasingly used in Thatcher's government and embedded into science policy (Agar, 2019). Whereas the Tyndall Centre was borne amidst a more conducive interdisciplinary and policy-relevant science culture in the UK (Weszkalnys & Barry, 2013). Fundamentally, different forms of interdisciplinary approaches emerge for different purposes and in different contexts depending on the future that is being imagined. By the point of CSERGE and Tyndall, society-environment interactions were beginning to be better understood as entangled systems and not separate arenas. This changing view of the world altered the perception of interdisciplinarity in the ENV trading zone and disciplines were no longer seen as antagonistic or competing but rather cohesive and integrated.

Nonetheless, ENV in the 1960s and 1970s, employed a group of diverse experts working in conjunction with one another with the broad aim of advancing scientific knowledge about different strands of the 'environment' for students and researchers further afield. Where interdisciplinary work did occur, in the combination of two or more disciplines to produce new insights and knowledge, disciplines already had pre-existing connections through shared methods, instruments, practices, or views of the 'environment' (Barry & Born, 2013). Cultures or models of interdisciplinary work emerged in spaces with much overlap, being more easily commensurable or intelligible and the ENV, as a trading zone, enabled this. As environmental concerns became more widely expressed in the UK and globally, e.g., specific political concerns and movements (Porritt, 1984) or social, justice and ethical issues of pollution governance (Bugler, 1972), ENV's knowledge-making evolved in tandem with the wider politics of the environment and embraced more fully social, political and economic ways of understanding the 'environment', which differed from producing problem-solving knowledge. ENV was shaping and being shaped by the wider developments in knowledge and social order (Jasanoff, 2004).

In sum, the realities of ENV's founding from (largely) physical geography and the earth sciences, with positivist epistemologies, meant other forms of knowing and disciplinary practices were not prioritised or seen as

important as the positivist approaches and so, interdisciplinary work beyond these sciences was not easily recognised or formed. Yet, the framing and intent of the vision set out by Zuckerman embodied and practiced by ENV, Clayton, and the WP administrators cultivated a shift in values and encouraged a collective and enduring belief that the 'environment' was worth knowing, teaching scientifically and producing socially useful knowledge to solve emerging environmental challenges. The materiality of ENV's early institutional culture reveals the division of practices between disparate 'environmental' ontologies. Interdisciplinarity is not a given in a trading zone, the practices and performances of researchers need to be aligned both ontologically and epistemologically and as time progressed, this culture transformed as more nuanced and shared understandings of the 'environment' came to be in ENV, from the knowledge ENV produced. The imaginary and vision of ENV continued to mould and be moulded by the changing epistemic and political contexts that (re)shaped how researchers became concerned with the 'environment'. Some researchers were becoming aware of the multiplicity of values (including financial) that ENV knowledge, through collaboration, began to cultivate and attract and alter their scientific practices accordingly.

CONCLUSIONS: INTERDISCIPLINARITY IN ENV

This paper has explored how interdisciplinarity as a form of knowledge-making for the new 'environment' played out in practice in the ENV 'trading zone' (Galison, 1997). The idea of interdisciplinarity was at the forefront of higher education and science reform, and key to Zuckerman's original proposal for the School, yet the institutionalisation of interdisciplinarity practices, as shown in this paper, was multiple and uneven at best. This created tension and resistance between the world Zuckerman imagined of a transformational and interdisciplinary 'environmental sciences' solving the challenges of society through novel and new knowledge and the world deemed practically achievable (or desirable) by the administrators of ENV. More importantly, this paper underscores the emergence of ideas and the social dynamics between researchers' willingness to collaborate and openness to share knowledge, methods and tools. Hiring and situating diverse disciplinary researchers in one institutional space will not suffice to produce interdisciplinary knowledge. Rather, what is required is an institutional culture that is open to innovation and researchers who are willing to see different perspectives or take alternate positions, and embark on new experimental projects that try to reconcile antagonistic epistemologies and ontologies to produce radically new perspectives (Barry & Born, 2013; Bogusz, 2022).

As I have shown this is not guaranteed or evenly distributed. Trading zones are as effective as the institutions in which they are embedded and the researchers for which they are created. For instance, interdisciplinarity in ENV was received well by the disciplines and individuals for whom methods, instruments, and ontologies of the 'environment' were shared – like atmospheric and ocean scientists or geologists and hydrologists – and who could embrace more similar models of work and work in reciprocal ways (Barry & Born, 2013; Pickering, 1995). On the other hand, collaboration through more 'antagonistic' models of interdisciplinarity (Barry & Born, 2013) between disparate disciplines, like political scientists and earth scientists for instance, was low-priority by researchers and even thought of as less worthy by some of the more natural scientists due to entrenched positions of viewing science and society as separate arenas. Unlike today, the recognition of entangled society-environment interactions is commonplace and interdisciplinary approaches are seen as vital to understanding present and future environmental change. Overcoming the perception of scientific authority between disparate or antagonistic disciplines is vital in ensuring cohesive, just and legitimate forms of interdisciplinary working. Future initiatives that promote interdisciplinarity as a solution to tackle the complex social and environmental challenges of the present may learn from historical cases like those I have detailed above to understand the practical and messy social realities of putting interdisciplinarity into practice effectively and understand better the historical context and imaginaries in which interdisciplinarity emerges as a desirable approach in order to shape more robust interdisciplinary approaches for the future.

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CONFLICT OF INTEREST STATEMENT

The author declares no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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ENDNOTES

[1] Letter from Solly Zuckerman to Christopher Ingold, 24/9/1960, The Zuckerman Archives, UEA, Norwich, UK. SZ/UEA/4/6.

[2] Frank Thistlethwaite to Solly Zuckerman, 6/11/1964, The School of Environmental Sciences unpublished archives, UEA. Norwich, UK.

[3] Draft advertisement for Dean position, 1/1966, The School of Environmental Sciences unpublished archives, UEA. Norwich, UK.

[4] For reasons unknown to the author, there is not historical record of correspondence detailing the decision to alter Zuckerman's original proposal.

[5] Environmental Sciences, Assistant Registrar to Registrar, 19/1/66 and 3/3/1966, The School of Environmental Sciences unpublished archives, UEA, Norwich, UK; The numbers were provided by Universities Central Council on Admissions.

[6] G. Eglinton to A. Katritzky, 10/1/1966, The School of Environmental Sciences unpublished archives, UEA, Norwich, UK.

[7] A. T.A. Learmonth to Frank Thistlethwaite, 25/1/1966, The School of Environmental Sciences unpublished archives, UEA, Norwich, UK.

[8] W.B. Harland to Frank Thistlethwaite, 3/2/1966, and D. Osborne to ENV WP, 8/2/1966, The School of Environmental Sciences unpublished archives, UEA, Norwich, UK.

[9] Hubert Lamb to D. Osborne, 29 December 1966. J.R. Jones Archives, University of East Anglia, Norwich, UK. UEA/Jones/40.

[10] A Report on The School of the Environmental Science, 1968–1981, Anthony Young, The School of Environmental Sciences unpublished archives, University of East Anglia, Norwich, UK.

[11] 52 enrolled students, 20 more than estimated. Student numbers, The School of Environmental Sciences unpublished archives, UEA, Norwich, UK.

[12] 36 out of 70 publications were sole-authored. 10 of 70 papers were published in Nature.

[13] Interview with David Dent, 2020.

[14] Interview with Peter Liss, 2020.

[15] Interview with Peter Liss, 2020.

[16] Interview with former Research Student (a), 2020.

[17] Interview with Environmental Scientist (a), 2020.

[18] Interview with Fred Vine by Paul Merchant, National Life Stories: An Oral History of British Science, transcript (p. 53), British Library, London, UK. C1379/25.

[19] Interview with Environmental Scientist (b), 2020.

[20] Not forgetting the intense debates, conflicts and disagreements concerning quantitative or numerical data in positivist sciences, and geography (see Barnes, 2004).

[21] Multiple interviewees noted this.

[22] Interview with Environmental Scientist (a), 2020.

[23] Interview with Environmental Scientist (c), 2020.

[24] Interview with Environmental Scientist (b), 2020.

[25] Interview with Environmental Scientist (a), 2020.

[26] Except for the Climatologists.

[27] Correspondence with Climatologist (a), 2020.

[28] Both CSERGE and Tyndall were formed as a result of external funding both with explicit remits for interdisciplinary research. CSERGE focused on examining 'all' aspects of decision-making with environmental resources, including collaboration between economists, political scientists, geographers, social scientists. Tyndall was formed to bridge the gap between climate scientists, social scientists and policy makers and to further promote interdisciplinary working around climate change.

[29] With exception of The Climatic Research Unit based at University of East Anglia.

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