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Storying connectivity and value: the south west creative technology network's cultural ecologies as network visualisations

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ABSTRACT

This paper explores the productive connectivity developed by university-industry knowledge exchange (KE) programmes for research and development (R&D) and their emergent cultural value. The South West Creative Technology Network (SWCTN) is our case study. We build on Dovey et al.'s. work to visualise the cultural ecology supported and created by cohort-led R&D programmes. Our visualisations, combined with interview data, evidence that new connections create diverse forms of value, including inspiration, mentoring, training, and recruitment opportunities, and cooperation through collaborative working. We supplement social network and visualisation tools with rich qualitative data to explore the "why," "how" and "to what end" of new connections, contributing to the field of Mixed Methods in Social Network Analysis (MMSNA). This methodology is novel to the field of creative economy research. We argue for new forms of R&D funding for the creative sector to take a cultural ecology approach if we wish to take seriously and invest in the diverse forms of value beyond economic drivers, sometimes described as "intangible," that play an important role in building regional capacity, innovation and productivity.

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Cultural ecology; cultural value; mixed methods; social networks; creative economy; R&D

Introduction

This paper visually maps the productive connections created and supported by a facilitated creative network to better evidence how such networks contribute to regional research and development (R&D) capacity building through the forms of value they produce. The South West Creative Technology Network (SWCTN) was a £6.6 million R&D project to increase collaborative innovations between universities and industry in the use of creative technologies from 2018 to 2021. Funded by Research England, it supported knowledge exchange (KE), prototyping products, and business growth. The regional partnership comprised the University of the West of England (UWE Bristol),

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Bath Spa University, Plymouth University, and Falmouth University, and two creative production studios, Watershed, Bristol and Kaleider, Exeter, in the South West UK, covering the counties of Cornwall, Devon and the cities of Bristol and Bath and their surrounding regions.

SWCTN's methodology stemmed from previous KE and R&D collaborations between members of the partnership, specifically UWE and Watershed (Dovey et al., 2016). SWCTN created opportunities for exchange and collaboration through a carefully curated workshop series and creative producer and knowledge exchange manager (KEM) support, with a core goal to build capacity for R&D across the region. It cultivated a diverse network, producing three cohorts of 24 funded R&D "fellows" representing industry, academic and new talent, as well as teams to develop prototypes, all recruited via an open call and application process. The cohorts convened around cross-disciplinary R&D themes: immersion, automation and data (Figure 1. See SWCTN, 2021). These themes were chosen in dialogue with programme partners as offering the greatest potential for innovation in the region's creative sectors, representing key challenge areas, and enabling partners to support the network through access to the expertise, skills and resources. The idea of cultural ecology put into practice by the SWCTN team is underpinned by the belief that diverse groups of people and talents produce more innovative and inclusive outputs

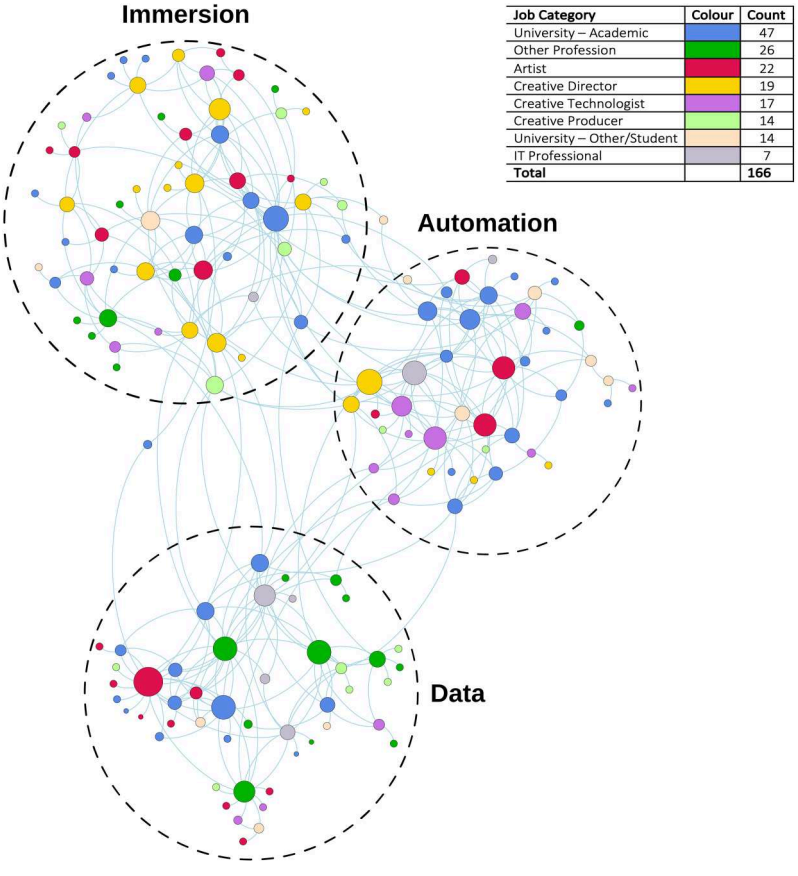

Figure 1. Network connectivity within and between SWCTN cohorts.

(Snowball et al., 2022; Wang et al., 2019). The team facilitated connections, created spaces of exchange, and provided support for innovators at all career stages to share experiences, skills and values, to collaborate and co-create. The SWCTN team is comprised of creative producers, academics, business advisors, creative technologists and KEMs from across the partner organisations. Creative producers offered one-to-one support to funded participants, were responsible for much of the curation, content and organisation of the programme as a whole, and made introductions for participants within the wider cultural ecology of the region, helping them build connections and confidence. KEMs connected participants to different expertise and resources in the partner universities.

Cohort-led programmes are relatively new in the UK KE context differing from forms of KE like industry-based PhDs or voucher schemes. They are intensive, co-produced and embedded in an ethic of diversity, inclusivity, generosity and trust-building, as a supportive and safe transdisciplinary space/community. Funded fellows completed an independent project as well as being encouraged to make new transdisciplinary and cross-region collaborations. SWCTN operated on a recruitment process rather than a membership model; the cohort was curated to purposely bring together a socio-demographic, disciplinary and sectoral mix. SWCTN, when compared generally with other "catapult" or "accelerator" programmes for innovation, had a high intensity of in-person, curated networking activity. This comprised 3 two-day workshops for each cohort, which moved to 10 3-h online sessions during the pandemic. It removed the onus on outputs to focus on process and exchange, which allowed participants far greater exploration, self-reflection, and creative freedom. Over 100 participants interacted with core SWCTN activity including workshops, demonstrations, facility tours and seminars.

We conducted research to measure and evaluate our network development. We tested the theory of cultural ecologies using social network visualisations to validate our methods for connecting people through cohorts for KE. Social network tools helped draw insight from the web of connections that emerged in SWCTN, exploring the range of values that connected people and led to collaborations, helping us to evaluate our success. Our work was exploratory and iterative. Social network analysis is an established methodology in creative industries research (Granger & Hamilton, 2010; Swords, 2022) but combining it with qualitative data is novel**.** Through the use of mixed method social network analysis (MMSNA) and visualisation approaches, we have been able to take different scales and lenses, combining elements of quantitative and qualitative data, to understand the meaningfulness of the connections identified.

This paper aims to:

– Illustrate how a cultural ecologies approach is put into practice in the creative technology sector and its related outcomes through visualisations
– Use exploratory social network visualisations to introduce more qualitative information into Social Network Analysis (SNA) and analyse the "why," "how" and "to what end" as well as the "how many" and "who" of social networks
– Understand the different forms of cultural value and meaningful connections necessary for innovation and capacity building within the sector.

The paper will first outline the thinking behind the cultural ecology approach and the case for using social network visualisations to illustrate it. It then outlines our

methodology before introducing our visualisations. These focus on specific constellations and scales of connections to derive further meaning about how networks are supported and evolve through R&D programmes and the types of value that emerge from them. In our discussion, we use ecological thinking to explore and make tangible the emergent connectivity and value to explore the weaknesses and opportunities of SWCTN's cultural ecology.

Ecological thinking for understanding cultural value

This paper builds on the work by Dovey et al. (2016) to visualise the cultural ecology approach as a way of demonstrating its usefulness. This research itself draws on theoretical developments by Holden (2015) and Markussen et al. (2011), among others, to understand innovation and value creation in the cultural and creative sectors beyond simplistic economic models. For Holden (2015), the ecological approach concentrates on relationships, patterns, and flows within the entire system, as something messy and dynamic. He suggests that the ecology of culture can be conceived as three highly interactive spheres: publicly funded culture, commercial culture and homemade culture. Using ecological processes like emergence, regeneration, positive and negative feedback loops, fragility and robustness, and mutual dependence, he gives a host of examples of the ways these three spheres overlap in the makings of both individual careers and in the cultural and creative sectors at the regional level. Many similar mechanisms are used to understand complex systems (both ecological and social) such as non-linearity, openness, path-dependence and adaptive behaviour, self-organisation and non-determinism (Comunian, 2011). This system terminology is helpful in understanding the unevenness and diversity of cultural ecologies and is perhaps most useful in describing the tension that exists in ecosystems between competition and cooperation, something that is often noted as a key characteristic of the creative economy (Bandinelli & Gandini, 2019; Markussen et al., 2011).

Markussen et al. (2011) point to the way that creative organisations share resources and space, with staff shifting across organisations, mentoring each other, all whilst being in competition. Bandinelli and Gandini (2019) describe this as "collaborative individualism" where creative networks offer an imaginary communitarian element enabling them to nurture social relations while at the same time pursuing individual professional success. For Komorowski et al. (2021; also see Banks, 2015 on economic vs cultural value) the commercial to the more public-funded/community facing operate on a spectrum; creatives are engaged in a mix of paid and unpaid work not only motivated by individual profit (Alacovska & Bissonnette, 2021; Roberts & Townsend, 2016). For economic purposes – the main way culture is understood in policy and funding terms – culture is broken down into reductive and atomised parts such as sub sectors, venues and business types. Holden argues, however, that culture consists "of moments when people and things come together in concatenations" or assemblages (2015, p. 3). Unlike economic approaches, creativity, new knowledge and expression are understood to be distributed across the cultural ecology rather than emerging from an "artistic core" (Holden, 2015, p. 11) that then has to be transferred, commercialised or "spillover" into the wider economy.

A cultural ecology lens reflects the co-created "value constellation" of much creative work in contrast to the linear value chain of economics (Dovey et al., 2016, p. 11). It

privileges a more multivalent understanding and helps to highlight the complexity and richness of social networks for creative technology R&D.

Cultural value in creative technology R&D

The current policy version of the cultural and creative sector emerged in the UK in the 1990s coined by the new "creative economy" prioritising new digital sectors contributing to high growth and exports and putting creativity at the centre of the knowledge economy. In this context, R&D that is more commonly associated with STEM subjects has been applied to creative sectors, however, definitions of creative R&D are still in development. Nesta (2017, p. 6) forwarded a definition comprising "creative and systematic work undertaken in order to increase knowledge – including knowledge of humankind, culture and society – and to devise new applications of economic, cultural or social value of available knowledge". Following this, UK Creative Industries Clusters Programme (2018–2023) began with a goal to develop a creative R&D taxonomy through its delivery suggesting further refinement was needed. More recent commentary from the Creative Industries Policy and Evidence Centre argues that the potential of Creative R&D remains unfulfilled and untold due to the economic bent of current definitions (Michaels, 2022). The instrumentalist view of the sector and its current forms of R&D is critiqued as narrowly economic, narrowly creative, and exacerbating a precarious workforce in an increasingly competitive sector vying for short-term contracts with low to no rights, security or benefits (Mould, 2018; Swords & Prescott, 2023; Walmsley, 2012). A few recent programmes have drawn together their own definitions of creative R&D that are less technocentric, prioritising cultural content/experience creation, and that are based on richness and diversity, creating innovation cultures akin to open innovation, collaboration, appropriately scaled support, openness, and green, inclusive and democratic outcomes (Clwster, 2023; Dovey et al., 2023). Like these, SWCTN designed application processes including call documentation that allowed applicants to demonstrate how their work represented creative R&D without being overly prescriptive in order to make opportunities as inclusive as possible.

Cultural ecologies as ontologies

Networks will always exclude some in their efforts to include others. Likewise, there are clearly issues of power being "naturalised" when ecological terms are transposed onto social systems (Greer, 2021; Roberts et al., 2017). Wells (2006) points out that the use of ecological metaphors applied to inter-firm competition has been selective and thus makes findings partial. While the ecosystem metaphor has been applied to a number of overlapping contexts for knowledge exchange – entrepreneurial ecosystems, industrial ecosystems, innovation ecosystems – often a dominant economic model is replicated in analyses, taking a narrow view of what the ecosystem consists of (e.g. isolating firms within a specific sector, sometimes using the triple helix of firms, public bodies and universities) and maintaining a linear view of innovation with levers dictating outputs. Understanding contexts for creative value creation as actual ecologies – ontologies – rather than metaphors allows for a more holistic understanding of the types of exchange that happen across different scales and actors (including the non-firm, non-human), the constant flux,

porosity, circularity and adaptation within the ecosystem as assemblage (De Bernard et al., 2022; Ghazinoory et al., 2021; Kuckertz, 2019; O'Connor & Audretsch, 2023). Thinking differently about creativity as an everyday tactic operating on a spectrum from amateur to professional creativity helps to redistribute ideas around value and power within cultural ecologies (Hawkins, 2019; Ingold & Hallam, 2007).

A cultural ecologies approach is recognised in broader human and cultural development frameworks as a more democratic, inclusive and participatory way of understanding culture (DISCE, 2020; Gross & Wilson, 2020) than the levers/outputs model. Ecologies display horizontal power and reframe individualised chains of production and economic output into more holistic webs of interdependencies in a way that moves away from narrow measures of GDP towards different forms of value such as quality of life, sustainability, wellbeing, etc. (Barker, 2020; Crossick & Kaszynska, 2014; Wilson et al., 2020). Importantly, these call for greater attention to how you manage, maintain and think about drivers and inputs of cultural ecologies. Bailley et al. (2019) introduced the concept of "environing" as an additional ecological metaphor that renegotiates the cultural ecology as a form of critique; through strategic actions and cultural activity, actors simultaneously work within and against current neoliberal modes of cultural policy and funding.

Thinking in cultural ecological terms can widen our thinking about cultural value and, as Holden points out, looking afresh at ways of valuing that is so ingrained in the status quo so as often to be taken as intrinsic and impossible to think otherwise. Using an ecological approach brings to the fore the multiplicity of participants, skills, values and impacts comprising creative networks. It embraces multiple "economies" such as the quadruple bottom line: its social, cultural, and environmental value as equal to its economic value.

How is cultural value defined?

Cultural value is defined variously across the literature from "aesthetic qualities" (Banks, 2015) to the capacities of culture to help shape reflective individuals, empathy for others, to produce more engaged citizens, support healthier communities and subjective wellbeing (Crossick & Kaszynska, 2014). It is defined as intrinsic ("art for arts' sake" – having value in and of itself) and extrinsic (adding value elsewhere, in more and less instrumentalised ways). A related term is cultural capital. Roberts and Townsend (2016) define cultural capital as benefits derived from cultural goods, activities and participation, having both material and symbolic value, and existing in tangible (heritage, infrastructure and artifacts) and intangible (stories, traditions, practices and values) forms. They stress the interdependency of cultural capital with other forms of capital, like social capital which forms through networks of trust, reciprocity, collective outlooks and values. This paper defines cultural value as the accrual of cultural and other interlinked forms of capital emerging out of networks of cultural production such as creative R&D or KE programmes and the ripple effects these have within the geography of the wider cultural ecology, for example through cultural experiences. It is not the value generated, which may also be generated by companies outside of the creative sectors, but the assembling of distinct "value constellations" in creative ecologies that enables creative work to happen.

Much work on cultural value is around a limited understanding of outputs derived from particular types of transactional partnerships (the triple or quadruple helix) and categorise

critical aspects of network building as "intangible" (Carayannis & Campbell, 2012; Komorowski et al., 2021). The value generation of creative networks is not fully understood, partly because it is difficult to monetise or measure and so communicate effectively to policymakers; therefore, much still needs to be learned about the micro aspects of dynamic relationships in creative networks in generating value (Komorowski et al., 2021). One way to make these tangible is to visualise and unpack stories of cultural ecologies in practice. Our use of social network visualisations puts this to the test through the example of SWCTN, seeking to foreground different forms of value.

Visualising connectivity, value and impact in cultural ecologies

Holden (2015) identified that network diagrams become unwieldy and lose meaning when trying to represent an entire cultural ecology, which might after all be understood as lots of micro-ecologies (smaller-scale clusters of connections and interdependencies). While measuring the number and density of connections are indicators of ecosystem health and resilience, the quality of a relationship is equally important. Dovey et al. (2016) visualised how academics, creative businesses, alongside other collaborators, interracted through KE programming, how new funding bids resulted from these collaborations, and how the sustainability of ideas and projects was due to interdependence with the wider cultural ecology. They argue that their social network visualisations demonstrate that an ecologies-informed method for generating R&D delivers and intensifies connectivity. They propose that further work is needed to understand the nature, value and temporality of the connections made. The development of our method below is a direct response to that call. We explore the relationship between the connectivity, value and impact in a cultural ecology in practice: SWCTN. As with Holden (2015) and Dovey et al. (2016), our focus is the supply side because this was where the SWCTN team intervened, curated and sought to intensify activity through the KE programme.

Method

We used mixed methods social network analysis (MMSNA) to explore the cultural ecology of SWCTN.

Visualisation has been a key part of social network analysis from its inception, from paper-drawn sociograms to computer-aided representations of big data (Ryan et al., 2014). SNA is broadly understood as a relational orientation towards sociological explanation. Myriad methods are informed by overlapping theories of transactions and exchanges, social capital, actor network theory and network society, as well as more ecological ways of understanding social relations as webs (Scott, 2017). While SNA is closely associated with quantitative methods, the "cultural turn" of the 1990s in social network research, called for a shift in "how networks have been understood from pre-existing structural forms to the notion of social constructions brought into being through stories and images" suggesting that networks can be studied through the narratives used to describe them (Ryan et al., 2014, p. 2). In-depth interviewing allows for the examination of the meanings, feelings, attractions and interdependencies on which the "social" dimension of networks is based (Ryan et al., 2014). A mixed methods approach to SNA is

able to bring the structures and density of networks together with the meaningfulness of social relations: the "why," "how" and "to what end".

Our social network visualisations draw on data gathered in a number of ways: through surveys, interviews and through email requests for numerical weightings. We mapped people, places, and outputs, testing how and where industry-university and inter-sectoral collaborations were resulting from the programme. Our social network method is "fused" or integrated (Hollstein, 2014; Yousefi Nooraie et al., 2020) because we are using both numerical and textual data as explanations and embedded within our network visualisations, and we have translated qualitative data into quantitative data to build more meaning into our network visualisations. We have not seen this combination used in other creative economies SNA work.

We surveyed SWCTN members annually to find out who they had connected with. The survey went directly to participants who had been funded (approx. 100) via Qualtrics software, where we were able to send reminders and monitor levels of response. We also sent a survey link via our newsletters to the wider SWCTN network (approx. 600). We allowed network members to self-select whether they felt they were sufficiently engaged with SWCTN enough to respond, whereas funded participants were contractually obliged to assist with project evaluation. We had 295 survey responses in total. Once we had merged the three annual surveys, accounting for duplication, we had 50 complete responses about new significant connections used in our network maps. We asked survey respondents to list their top six most significant new connections, allowing them to decide what qualified as significant to them. We then asked for the name, company, job role, location and a brief summary of what the interaction with the person looked like, and whether any outputs had arisen from the interaction (new work, new commissions, new publications, etc.).

In-depth semi-structured interviews were designed to find out who, how, and why people were connecting, to better understand how SWCTN was supporting different mechanisms for KE and what value derived from this. The interviews were loosely narrative and asked participants to chronologically reflect on their experience of participating in the programme, using prompt questions like "who did you connect with in the early workshops?", "were there any moments that particularly inspired you?", "did any stand out conversations happen?" or "who have you continued to connect with?". 57 interviews were conducted in total. Qualitative data was coded using NVivo, first through a code for "new connections" then using grounded theory to establish the quality of connections. From this, we derived five emergent connection types from the coding process: inspire, guide, train, recruit and cooperate. Table 1 provides definitions. We emailed participants with a list of their connections and asked them to ascribe a number to each connection that weighted the quality of their relationship. Although we recognise that an inspiring conversation could have been more significant than a collaboration, we decided that adding an additional layer of weighting around the significance of each connection type would be confusing to participants and would add further complexity to the social network visualisations. For simplicity, we weighted inspire as the weakest form of connection with cooperate being the strongest, referring to a sustained collaboration such as the development of a new project or funding bid. The rationale for this was that "inspire" and "guide" were more likely to be based on a one-off encounter and less likely to result in a tangible outcome, whereas "train", "recruit" and "cooperate"

Table 1. Total count of connection types across automation and data cohorts.

Connection Type	Connection Description	Count of Connections: Automation Cohort	Count of Connections: Data Cohort
Cooperate	Sustained interaction(s) or collaborations.	28	31
Guide	Provided or received guidance and/or assistance.	18	23
Inspire	Provided and/or received training, skills transfer and/or mentoring.	17	17
Recruit	Recruited and/or was recruited for paid work.	4	8
Train	Worked together on a common goal.	7	7
Totals:		**74**	**86**

were more likely to refer to multiple encounters or an ongoing relationship and a tangible outcome.

We used open-source software packages Gephi and DMX, as well as LucidChart to visualise SWCTN's emerging relationships. Gephi was suited to visualising and analysing our wider network, while DMX captured richer detail, adding further meaning to connections. Gephi is an open-source visualisation and exploration software for network and graphs.[1] DMX is a semantic data platform to map, explore and share networked information with meaningful relationships.[2] LucidChart is an intelligent diagramming application to clearly document systems and processes.[3] Although we have used Gephi to create the visualisations in this paper, it could not have happened without ongoing conversation with the DMX team who helped us clarify our thinking around categories of relationship and outputs, which we also mapped in their software. In Gephi, we initially used algorithmic layouts in Force Atlas, which mimics a physical system where nodes and edges repel and attract each other to settle in a balanced configuration, to understand the structure of the network, then manually moved nodes to create clarity, particularly where connections were densest.

It is important to remember that the visualisations are not a complete representation of SWCTN; the mapping only reflects the connections of those who participated in surveys and interviews. In addition, we have zoomed in on "micro-ecologies" which better enable us to view, understand and articulate the quality of the connections and analyse value emerging from them. These are partial and reflect an imposed boundary necessary for the introduction of qualitative information to be fused into SNA. It is also worth noting that we have merged participant responses from different collection methods and timeframes across the project lifespan so there is limited temporality displayed through the visualisations. The visualisations are exploratory and iterative; we trialled different approaches as we went along. We have focused on data from two thematic cohorts in SWCTN – Automation and Data – because their participation in SWCTN was synchronous with this research.

Visualising a network: ecologies at different scales

The first visualisation we created shows new significant connections made by SWCTN participants both *within* the three cohorts of Immersion (27 funded participants), Automation and Data (both 24 funded participants) and *between* them: this can be understood as the cultural ecology that the SWCTN team curated and operationalised. Individuals are represented as dots – *nodes* – with their new relationships represented in the lines –

edges – that connect them. The greater the number of meaningful relationships made, the larger their dot appears in the network visualisation. On average, SWCTN members told us they had made 12 new useful connections from their contact with the Network. This number rose to 19 for those who had participated in cohort activities.

Figure 1 shows a high degree of interconnectivity within (where the SWCTN team facilitated engagement) and between the cohorts. Non-fundees appear at the edges of the visualisation as smaller dots and illustrate how core network activity is linked (e.g. through public events and KE) to wider SWCTN membership representing the cultural ecology of the South West UK. The Data cohort had fewer connections amongst themselves while also having the highest proportion of connections developed outside of their cohort. However, this could be skewed by a slightly smaller number of responses from the Data cohort, due to online programming during COVID-19, and shorter timeframes as the last cohort.

What Figure 1 does not tell us is what those new connections involved. Figures 2 and 3 examine what types of connections were being made and what value they held for Automation and Data cohorts. They evidence the diversity in relations created across different job roles. For this paper, we have narrowed the data to a selection of individuals who had high levels of interconnectivity so the figures are not representative of the full data collected from each cohort. They are instead illustrative, aiming to highlight the different types of interaction in a visually accessible way.

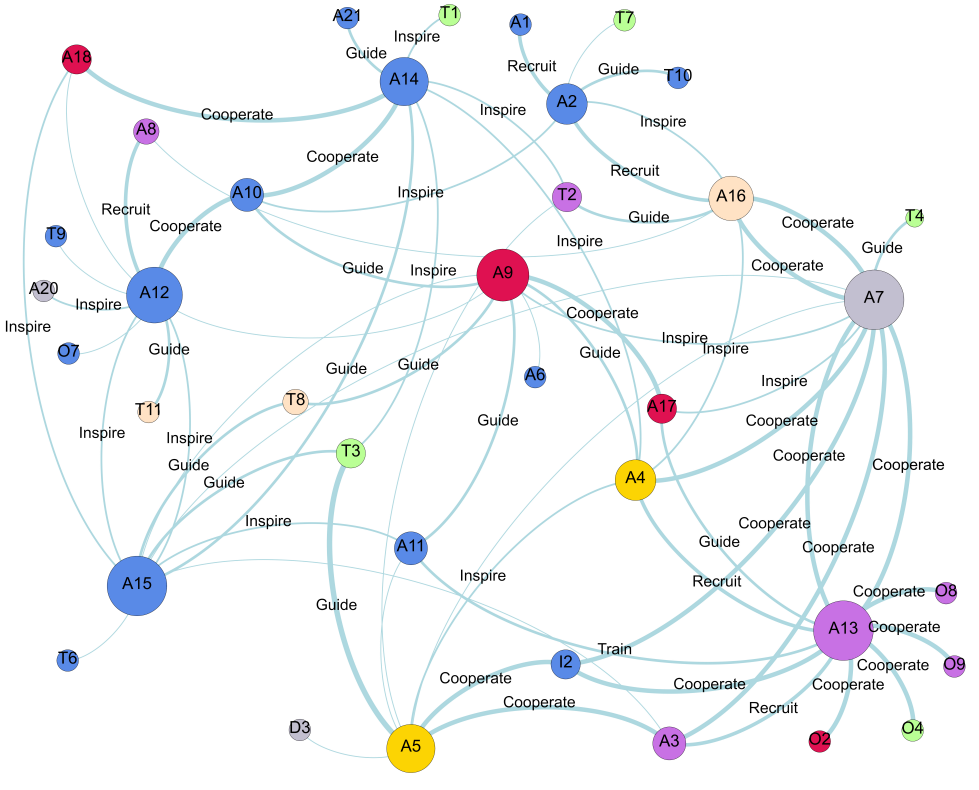

Figure 2. Network map of weighted connections for selected automation fellows.

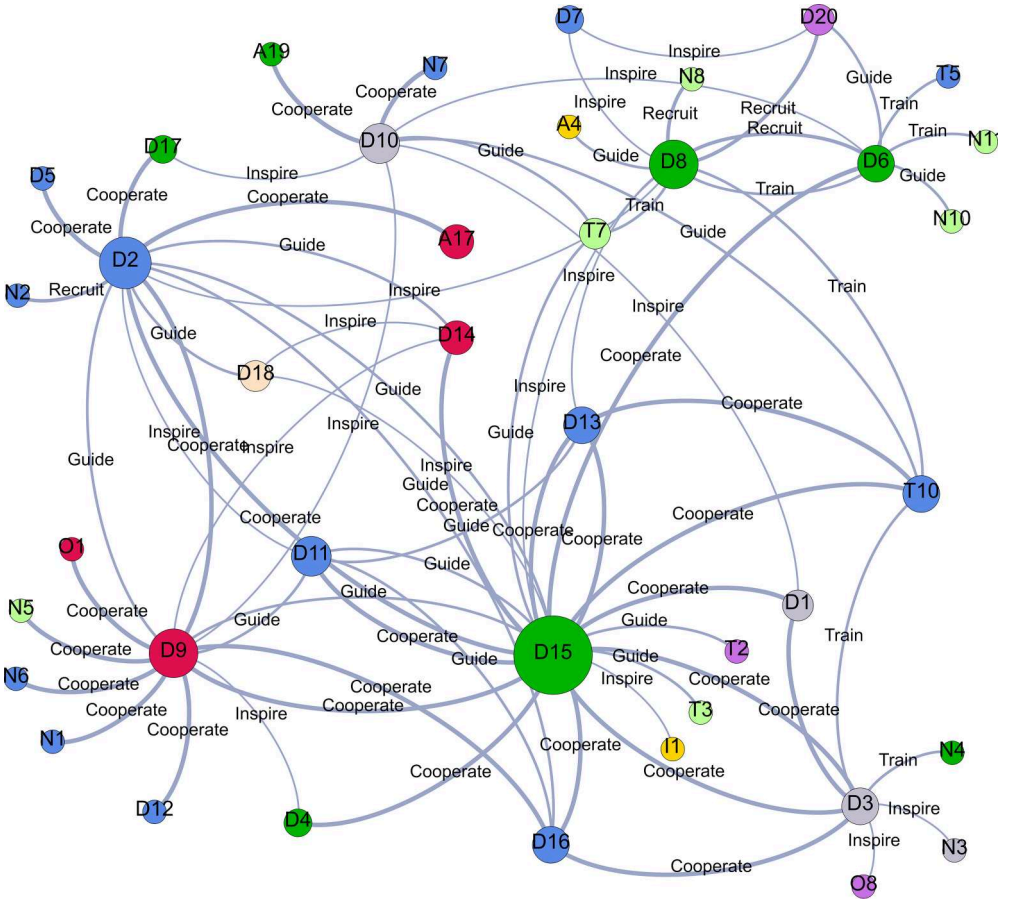

Figure 3. Network map of weighted connections for selected data fellows..

The thickness of the edges and their labels correspond to five categories of interaction: inspire, guide, train, recruit and cooperate (Table 1). A similar spread of connection types can be seen in both cohorts, with cooperation and guidance accounting for the greatest level of meaningful connections emerging from the SWCTN experience. Inspiration, while weighted as the weakest form of connection, was also highly influential to participants. Across the first three visualisations, which use the same colour coding throughout, there is a clear indication of the mix of sub-sectors that comprise a creative technology ecosystem.

Figures 2 and 3 also add further detail about the connections across the cohorts, the SWCTN team, other recipients of SWCTN funding and non-recipients through the Unique Identifier Codes ascribed to each node (see Table 2). Figure 3 shows a Data Fellow (D8) made numerous connections to other Data Fellows (D2; D6; D7; D8; D15; D20), as well as an Automation Fellow (A4), two SWCTN team members (T7 and T10), and a non-recipient of funding (N8). Figures 2 and 3 tell us more about the quality of connections in cultural ecology, but they do not give a sense of how relationships build over time or what the outcomes of the relationships are in terms of wider value creation. New collaborations resulted in numerous outcomes, not all tangible outputs with economic value. In the following section, we focus on the importance of the processes of value

Table 2. Overview of unique identifier codes.

Unique Identifier Code (UIC)	Explanation
A …	Node represents a member of Automation cohort
D …	Node represents a member of Data cohort
I …	Node represents a member of Immersion cohort
N …	Node represents a non-recipient of SWCTN funding
O …	Node represents a recipient of SWCTN funding outside of cohorts
T …	Node represents a member of SWCTN team
… 1/ … 2/ … / … n	Node represents the n^{th} participant from each group

attribution in building connections and capacity rather than having a narrow focus on outputs: output as a result of value rather than value equating to output.

Telling stories of connectivity

This section stories three examples to explore how we visualise and bring together mixed methods to provide better evidence of the productiveness of a cultural ecology approach for building the capacity of the creative technology sector in the SW UK. The three examples were selected to highlight different forms of connectivity, exchange and value and aim to demonstrate how the cultural ecology assembles. The examples include: Taylor, a freelance creative technologist; Charlie and Wren, fellows who formed a Community Interest Company together; and spaces of collaboration that emerged out of the Data cohort.[4] We draw inspiration from Holden's ecological terminology, from the language of complex adaptive systems (as defined by Comunian, 2011 to analyse creative cities) and our conceptualisation of cultural value to understand the relationships at play in creative ecologies.

Example one: the freelancer

A Philosophy and Politics graduate, Taylor (A7) worked in the charity sector before retraining as a web developer. They left their permanent job to commence the SWCTN fellowship. They have since been working in a freelance capacity, doing web development "bits and bobs" as well as more creative technology-focused roles.

Taylor found that the initial workshops where they were "meeting so many people all at once" was a very intense process. Early on, Taylor met their creative producer, SWCTN's creative technologist, and began conversations with Drew (A4), Ash (A16), and, Nell (A13), fellows who had similar interests and experience levels.

Through serendipitously meeting an Immersion fellow, they connected with Immersion cohort fellows and creatives outside of SWCTN, who were working together to create a network of women in technology. Taylor also felt supported by Frankie, the organiser of a conference Taylor signed up for, who persuaded them to give a presentation on their SWCTN research:

> She is really amazing at supporting women getting into tech. And she separately put me in contact with lots of people. (Taylor)

By the end of their fellowship, Taylor had built on early workshop conversations and was running workshops with Ash and collaborating to be named on applications for

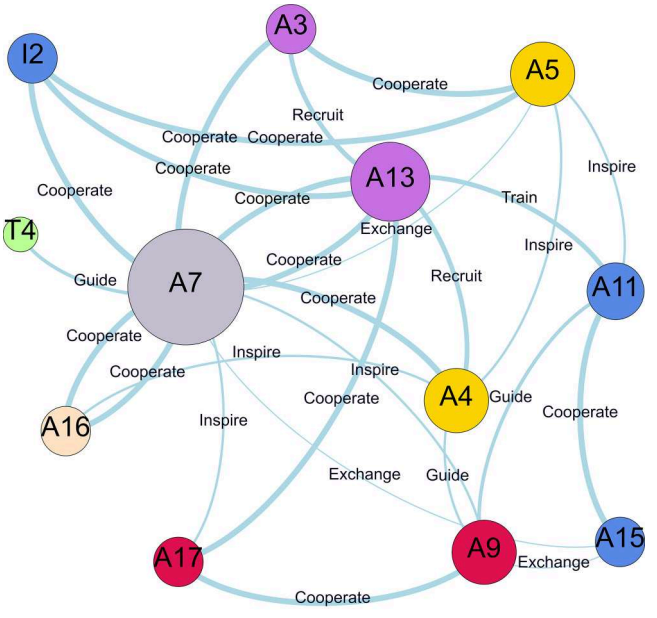

Figure 4. Network map of weighted connections for Taylor with 1 degree of connection.

three SWCTN grants to create a technology prototype (A3, A4, A9 & A17 – see Figure 4). Web developer skills were an important asset to Taylor that others in the cohort valued, recognising it as a skills gap in their projects and choosing to recruit from within SWCTN. Taylor was able to utilise a specific set of skills as a creative technologist:

> We had an amazing web development team who were both SWCTN alumni and one was Taylor … And they were awesome, because they could work with that ambiguity again. If we'd just been out to "Let's get a web developer", they would have gone nuts [with the ambiguity]. (Automation prototype team member)

Taylor gained short-term contracts from SWCTN prototype grants but the fellowship had re-energised them towards further study, beginning a part-time MSc and looking for a full-time developer role as we emerged from the global COVID-19 pandemic. For a short time, SWCTN enabled them to sustain a freelancer career as a creative technologist. They are an example of the way that individuals in the creative technology sector can benefit from funded R&D cohorts to develop their networks into new sectors and operate within a cultural ecology as a key node person connecting across multiple projects with an in-demand skillset. They also, however, highlight the precarity of such work as an independent entity, especially during a moment of crisis for much of the sector during the pandemic (a shock to the ecosystem), although their skillset and the support they gained from SWCTN enabled them to adapt. This suggests the need to provide more support that builds and strengthens cultural ecologies and collaboration within them and identify business models that reduce risk and precarity for freelancers who assemble across multiple micro-ecologies, strengthening the ecosystem but not necessarily themselves.

It at first seems like there is mutual dependence between Taylor and the teams they gain short-term contracts from, but it is difficult for them to sustain the number of contracts they need to remain a freelancer. Their role in the ecosystem is fragile and more one-directional in that those who gain from their skills benefit from the relationship more than they do in the long run. To an extent, Taylor is trapped within the path-dependence of the neoliberal freelancer trajectory of seeking out portfolio work and has to adapt. Cultural ecologies are open systems and Taylor's new path to undertake MSc work kept their options open to enter back into the system in the future. SWCTN built their confidence to progress in the field, even sideways. While Figure 2 shows that Taylor had a high number of "cooperate" connections it does not illustrate the short-termism or dynamism of those connections or the tangible and intangible value they created. Taylor contributed to a tangible output of a new prototype and gained intangible benefits like increased confidence and time for career reflection and planning. When only valuing tangible (economic) outputs it neglects the potential of these latent connections and intangible value to reassemble or become translated into other forms of value at a later date. It also negates the need to nurture the ecosystem as a whole, and in an ongoing capacity, rather than just injecting output-targeted support.

For Taylor, the impact of participating in SWCTN has been far wider than the employment they gained: it has increased confidence; linked to a key creative hub; built new connections and a support network; given time to think about and develop interests and skillsets. This capacity- and confidence-building is crucial to operationalising a cultural ecology approach; through supporting those entering the creative technology sector, SWCTN platformed regional talent development.

Example two: the community interest company (CIC)

Wren and Charlie were Automation Fellows who successfully bid for a SWCTN prototype grant and created a business together to complete the work (Figure 5).

Wren is a maker of large outdoor artworks. They previously taught art to young offenders to top up their income. In recent years they sustained a creative freelance career "not making mountains of money but enough to keep us building projects" and consultancy work: "but it has always been like hunting down the next commission … working out where we're going next; oh my god, we've run out of money". Wren's career exemplifies Holden's claim that cultural ecologies have overlapping spheres of public and private culture, with Wren supplementing their income with public-funded teaching. When Wren saw the SWCTN advert they realised "It was literally what I'd been wanting to do with my practice for about three years".

While Wren approached SWCTN from the Arts, looking to increase their technical skills, Charlie had "done a lot of start-ups and worked in the tech industry, and I very purposefully left that," joining the network to explore more creative and ethical aspects of their work. For Charlie, "working as a digital artist, in the non-physical space, I grabbed hold of people who did physical forms of making". Wren describes:

> I was like, "well, you're in [city], and I'm in [city]", and then … we realised that like artistically, the things that we really cared about were really similar … it's really important to us that we look at inclusion in our practice … the way we work together is really nice, and really collaborative … a lot of really mutually beneficial skills. (Wren)

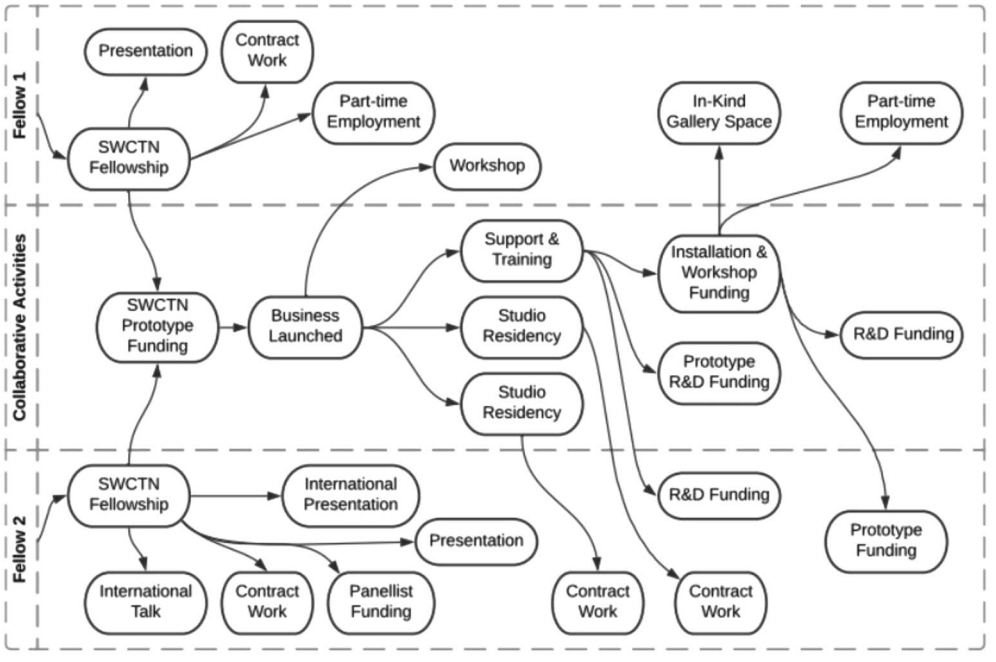

Figure 5. Mutuality and independent activity in Wren and Charlie's micro-ecology.

Wren and Charlie represent a mutualistic relationship offering each other complimentary skills which create positive feedback loops and new opportunities for them both. The value they derive from this relationship is more than economic. They value learning from each other and having a positive working relationship seeking shared goals.

After winning R&D and Arts Council funding they launched a CIC and generated new work with partners in arts, live performance and welfare sectors stemming from their SWCTN ideas and connections. They received COVID-19 recovery funds to diversify their business model creating "a really good community art piece in a box," sellable items to reduce dependencies on in-person formats.

> We're broadening out what we're doing to allow us to support our research arms and to make these social changes, because it matters so much to us. (Wren)

The development of a slow, inclusive, co-design approach that began with their SWCTN fellowships continued. Wren used part of their funding and the security it has given them to help others.

> We built in a set of micro-grants for disabled artists to have their voices heard, because we felt like it was really important that we could support as much of the wider community as possible at what's a really difficult time … (Wren)

SWCTN gave security to begin environing – exploring options for more ethical and sustainable work practices, supporting those less robust and creating positive spill-over for the community through their adaptive behaviours, decisions made about business structure (CIC rather than Ltd), and the types of work (ethical, inclusive and user-led design) work they seek to promote.

Wren and Charlie developed strong relationships with the SWCTN team at city-level meet-ups. Academic, Terrin (T6), became a significant part of the security Wren talks about. Wren describes showing Terrin their work as a pivotal moment, where they were confronted with academic rigour being applied to their process:

> I had this drawing and I was like, "oh, I want to make this thing", da-da-da-da, and Terrin was just like, "but why do you want to make it?" … it was a bit of a sucker punch, but it was so good, because I came back thinking, well, why is this important to me? (Wren)

Wren and Charlie gained access to the University's creative technology hub, which enabled them to begin production and connected them with new people in their city.

The impact of SWCTN was farther reaching than "keeping afloat in a pandemic." Their mutuality does not rely on dependency as they are both able to carry out independent activities alongside their collaborations. Wren upskilled and gained financial security. Charlie presented internationally and gained university teaching contracts. However, it was the efforts of the SWCTN team to be inclusive that were impactful. Wren noted they do "not come from a background where it is possible to meet with technologists and academics" and Charlie described how their learnings from SWCTN spread into new networks:

> … coming from the background of having a disability … SWCTN helped me find creative ways to be more independent, challenging the barriers I experience in a creative form. I have shared the experience and ideas with marginalised people whose experiences are similar to my own. (Charlie)

We can see the multiplier effect of cultural ecologies in practice strongly at play in Figure 5. By capitalising on resources gained through SWCTN they were able to embed themselves in new professional, creative, and academic communities, which gave them access to new forms of work, funding, support, and training.

Wren and Charlie's network visualisation evidences the non-linearity of creative work and the different types of values and outputs that emerge such as confidence-building and exposure to new ideas and people. While we have used LucidChart to create Figure 5, there is increasing potential within social network software to build linked outcomes and temporality into visualisations through interactive online interfaces. Visualisations are always selective processes and Figure 5 excludes the ripple effects within the cultural ecology that SWCTN funding clearly had through Wren and Charlie's environing. There is scope to include secondary impacts for non-funded recipients within the wider cultural ecology but the level of detail within the visualisation would need to be considered when dealing with a potentially large number of edges emanating from each node. A dynamic interface that allows for filtering would retain simplicity and readability at the same time as adding complexity and scale.

Example three: the artist, the architect, the analyst and the academic

The Data cohort were not as strongly connected internally due to the COVID-19 pandemic. Both the SWCTN team and the fellows worked harder to create spaces of exchange and collaboration.

Mapping relationships between Data fellows required an understanding of the formal and informal collaborative spaces that emerged out of the cohort and as key nodes of connectivity. Data fellows connections were strongest through the spaces of

collaboration but in a multi-directional rather than always reciprocal way; how they self-reported their relationships with each other was not always as strong (i.e. two fellows did not necessarily identify each other as significant connections) and it was the collaborative spaces that brought them together that were important. This echoes Holden's description of much work in cultural ecologies occurring in short-term concatenations. Our final experiment visualises the importance of shared spaces for exchange and collaboration and the emergent value.

The four spaces of collaboration were: practitioner workshops to advise on an MSc programme; a web resource created as an "external sharing" requirement of the fellowship; a Zine created by a group of fellows; and weekly Zoom coffee mornings (Figure 6). Other than the optional, online, informal "drop in" coffee mornings hosted by the SWCTN team, the collaborative spaces were self-initiated by fellows.

Val is an architect who joined the fellowship hoping to make stronger links in the South West and reorient their architectural practice towards data and research expertise. Likewise, Jean, a Bristol-based artist was seeking to re-situate themself in the Bristol community after a lot of international work. Kai, an academic in architecture, was looking to find people with interdisciplinary skillsets like their own to bring something new to their research and university department. Sam, a digital social enterprise and cooperative founder, joined the network in the hope of building a new arm of their company. Val was active in all four spaces of collaboration. Sam initiated the web resource and contributed to the Zine. Jean was part of the Zine and the MSc workshop and Kai initiated the MSc workshop and contributed to the Zine.

The spaces of collaboration brought these disparate individuals representing very different sub-sectors of the creative economy together in a spectrum of formal and informal relationships resulting in different forms of value. Figure 6 clusters them. Val identified that experiencing these multi-disciplinary groupings empowered them to broach more radical collaborations in their future work. They anticipated future collaborations to emerge with Jean through a discovered mutual interest and with Kai in continued interaction with the new MSc. Through creating a collaborative space for industry input from their Data peers to feed into their MSC course, Kai was able to justify an updated, re-designed syllabus to their faculty.

Sam and Val were two of four members of a website resource that evolved through the need to have an external output as part of the fellowships. The resource is as an ongoing space for exchange, representing diverse voices and crowdsourced content. The zine enabled those without arts backgrounds to experiment with creative content and methods and engaged creatives with a different format. Fellows found the zine to be a playful and low-risk space to experiment and collaborate with a smaller group outside the formal workshop space. A Friday morning online "coffee shop" became a central form of support for some fellows, gaining feedback, giving space to more meandering conversations and a social component (missing from online workshops), peer support and mentoring. Val valued this so much that they decided to ensure it continued beyond the programme funding, with fellows taking turns to "host". Fellows involved in these emergent collaborative spaces benefited from "intangible" value of finding mutual interests, ideas exchange, safe spaces to creatively experiment, advice, support and encouragement, best practices, new friends, ways of working, and access to opportunities and environing – opportunities to be playful and experimental, to be able to

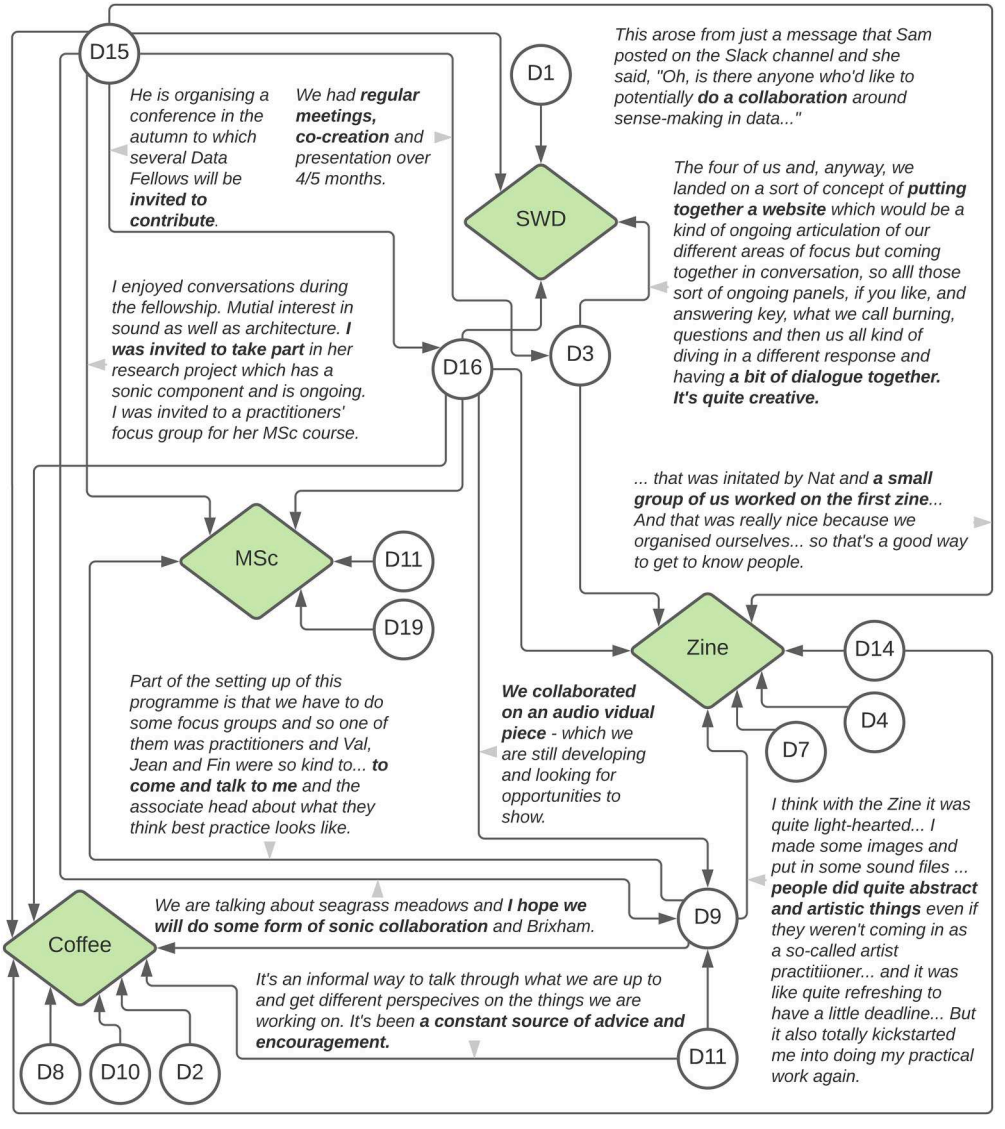

Figure 6. Map of selected collaborative spaces used by data fellows.

influence and create change (for example through lending their collective weight to enable a shift in the syllabus at a university) (see Figure 6).

The self-organising and non-deterministic components of creative social networks are highlighted; the SWCTN team could not have predicted these spaces of connectivity. The Data fellows came together to create these spaces and build their relationships with each other through those spaces. Formal and informal spaces of collaboration emerge as significant ways the network sustains itself. These collaborative spaces complicate our understanding of value within the system as inputs and outputs. Thinking ecologically allows us to understand them as both, representing the result of connectivity and value creation and creating new value and connections. As outputs of the network,

they do not have any economic value but held other significant value. Collaborative spaces function as connective tissue; cultural ecologies need these spaces of encounter. This example also brings to focus the need to understand knowledge exchange within cultural ecosystems as more-than-human or purely inter-firm.

MMSNA for evidencing the value of creative KE programmes

Our three examples shed light on the way people connected in SWCTN and the multiple forms of value emergent from those connections. In turn, this evidences the way regional capacity for KE and R&D can be supported via a strong network for the creative technology sector in the South West UK. We suggest this methodology translates across R&D foci and geographies to have implications for university-industry KE initiatives globally.

We used social network visualisations and stories of value to create a better understanding around the "how," "why" and "to what end" of cultural ecologies. We demonstrate how cohorts participating in a KE programme for creative technology R&D were given opportunities for emergent connectivity across disciplines, sectors and places, leading to innovation and productivity through capacity building for R&D. We offer examples of alternative forms of value that exist beyond economic outputs that often are described as "intangible" providing new vocabularies to measure success: confidence building, gaining support, feeling inspired, having time and space to plan, doors opening. Taylor gained confidence to take on part-time study. Wren valued the feeling of belonging to the group as someone who was often excluded from creative technology spaces. Val had doors open to seek more radical collaborations.

Case studies on Creative R&D programmes often focus on the shiny new product they created. KE and R&D programmes report on key performance indicators to show their value for money. These KPIs are often output driven, with a focus on jobs, commercialisation of products and IP. Academic research on innovation and entrepreneurial ecosystems highlights similar things at regional or national scale. These were seldom the forms of value that SWCTN participants chose to report themselves, favouring to talk about the "intangible" forms of value made more tangible through MMSNA in this paper. It is rare to see personal stories of participating in such programmes and what it meant for individuals to collaborate this way. By storying and visualising some of the "intangible" processes and outcomes of knowledge exchange in cultural ecosystems, it is possible to articulate diverse forms of value and identify how they can best be supported. Through coding qualitative data into a taxonomy of connection types, the visualisations also show that a cultural ecology requires these other forms of value – inspiration, guidance, and so on – as inputs and outcomes. This is an essential part of the constellations of value creation in a cultural ecology and needs to be invested in to the same degree as tangible infrastructure such as funding calls and building new creative venues. Further research might look to creating a taxonomy similar to the connections typology in this paper to create a stronger language to communicate multivalent outcomes to funders and policymakers.

Our social network visualisations are iterative and imperfect, reflecting continued efforts to better integrate quantitative and qualitative information on social networks through fusing methods. Social Network software was suitable to visualise networks of people, but as we sought to visually describe more complex ecologies of inputs,

outputs, values and collaborative spaces, other visualisation tools were more helpful. Gathering data at the scale of an R&D network of SWCTN's size, anonymising it, cleaning and translating it for use in social network software requires a huge time resource. There is potential to develop this methodology to incorporate a greater taxonomy of connections and to add weighting into each category, to add wider or secondary impacts within a cultural ecology, and to examine relationships between connections, values and outputs. With newer, dynamic interfaces for social network mapping, including live participant mapping it is possible to incorporate greater complexity and meaning into maps.[5]

Using ecosystems terminology gives pause to think about processes of KE and R&D in more nuanced and analytical ways. Identifying when connections are mutually supportive or increase precarity for certain parts of the ecosystem, whether they create positive feedback loops, whether they are self-determining and the degree to which they are open, scalar and porous, allows us to think about how cultural ecosystems need to be supported beyond short-term linear input-output mechanisms and might flourish with differently oriented policies. When we think about the interdependencies within an ecosystem being severed by external shocks like COVID-19 as having personal impacts of precarity, financial ruin, mental health issues, ability to access financial support, or bolstered by interventions like KE programmes, we can see that ecosystems are never neutral or stable, and that thinking ecologically is more than a useful metaphor.

Responding to Dovey et al.'s (2016) call for further work to understand the nature, value and temporality of the connections made through a cultural ecology approach to creative R&D, this paper foregrounds other forms of value than the celebrated economic value of the creative economy. The paper broadens understanding and logics of value within creative economies policy and funding with a view to create change. By taking an ecological approach, SWCTN itself and many of the fellows it supported represent points of environing along the quadruple bottom line while operating within existing neoliberal creative and university-level economic pathways.

While we have given three discrete examples, it might be better to think of these as fragments of the concatenations of relationships and values that comprise the whole cultural ecology and, aggregated, these create something greater than the sum of its parts. Social networks automatically exclude as well as include and this paper does not have space to address the implications of this but recognises it is an important consideration for future research. From a policy perspective, we might ask where in the cultural ecology can funding and other support mechanisms enhance the diversity of networks, the diversity of value they produce, and promote all individuals, businesses and spaces of the cultural ecology to thrive?

Notes

1. https://gephi.org/ (This paper is focused on exploring connectivity in a KE network and so we used Gephi's functionality primarily to measure a count of connections).
2. https://dmx.berlin/.
3. https://www.lucidchart.com.
4. We have changed all the names of participants for anonymity. We also use unique identifiers to correspond with the network visualisations.
5. In more recent projects we have worked with a company who offer this: https://freeicecream.co.uk/.

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