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The construction of new scientific norms for solving Grand Challenges

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ABSTRACT There is an increasing recognition that there is a class of problems that society must solve urgently in the twenty-first century if humanity is to survive into the twenty-second century—the so-called 'Grand Challenges'. Science policymakers have been active in recognising these challenges and the attendant need to develop new multidisciplinary ways of working. But embracing multidisciplinarity is not a straightforward choice for scientists, who individually are strongly steered by norms and values inculcated through their past scientific experiences. In this paper, therefore, we ask whether new funding approaches can contribute to creating new ways of working by scientists towards challenge-driven research, specifically by changing scientists' expectations and beliefs. We address this research question with reference to a single new experimental method, the 'research sandpit', implemented experimentally in a single national science system, Norway. Our data are derived from interviews with scientists involved in the five research projects funded as a result of the first sandpit, called 'Idélab' (idea lab) and held in 2014, and with the Research Council of Norway. We conclude that the sandpit approach appeared to shift research perceptions of individual scientists, particularly around long-term belief structures. This implies that, when well managed, the sandpit model can indeed be useful to generate multidisciplinary research as part of a multifaceted approach to funding scientific research.

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Introduction

There is an increasing recognition that there is a class of problems that society must solve in the twenty-first century in order to survive into the twenty-second century (the so-called 'Grand Challenges') ranging from climate change and resource scarcity to urban inclusion and security and human rights, but are all what Ackoff, 1999 (pp 99–101) calls multidisciplinary 'messes'. These demand novel multidisciplinary knowledge, which we define as a 'collaborative approach involving many disciplines' to produce concerted, coordinated social change in the face of often strong resistance from vested interests without necessarily leading to the formation of new interdisciplinary or transdisciplinary communities (National Research Council, 2001: p 8; Klein, 2010). Science policymakers have been active in recognising the need for new multidisciplinary ways of working, orienting research funding specifically to solving Grand Challenges (Amanatidou et al., 2016). Exemplary here is the European Commission's Flagship Horizon 2020 scheme, which seeks to stimulate excellent useful knowledge and whose work programmes, organised around six overarching challenges, favour large multidisciplinary consortia.

This science policy community response envisages that changing science funding will change scientific behaviours, specifically encouraging multidisciplinary approaches. But multidisciplinarity is not easy to produce (Klein, 2010), and the H2020 scheme has been criticised for the low volumes and superficial involvement of social sciences and humanities (SSH) disciplines in supposedly multidisciplinary consortia (cf. section 'Multidisciplinary research and the Grand Challenges'). In response to this, a number of research funders have proactively introduced new science-funding repertoires—such as research 'sandpits'—to reward individual scientists who embrace these changes, hoping to steer their science systems towards creating multidisciplinary knowledge (May and Perry, 2014). These new funding repertoires seek to change scientist behaviours, but scientific behaviour is steered by norms and value judgments inculcated through past scientific experiences (Knorr-Cetina, 1981), reflecting that science achieves collective coordination encouraging individuals to take choices based on anticipating their peer communities' norms and value judgments (Gläser, 2012).

These norms and value judgments vary widely between scientific communities (Olmos-Peñuela et al., 2015), and divergent norms and value judgments could undermine multidisciplinary working even with the introduction of these new policy instruments. We therefore ask whether these new funding approaches can contribute to creating new ways of working by scientists involving shared definitions of good scientific practices. We argue that these new approaches can succeed where participating academics learn shared norms and expectations, and we thus operationalise our research question as: can multidisciplinary communities build up through social learning processes the shared value frames necessary for common scientific activities? We address this question through an exploratory study of a single policy experiment, a 'research sandpit', implemented in Norway. This case study provides a means to better understand the relationships and dynamics within these learning communities, and we in particular identify the apparent disconnect between desirable practice and visible behaviours. Within the limitations of this exploratory, hermeneutic case, we contend that more consideration needs to be given to understanding the dynamics of these multidisciplinary problem-defining communities to realise academic science's potential to contribute meaningfully to solving the twenty-first century's Grand Challenges.

Understanding challenge-led research as a social learning problem

In this paper, we are concerned with multidisciplinarity out of a simple and pragmatic recognition that the majority of contemporary scientific effort remains organised, coordinated, and funded within disciplinary communities to which scientists generally identify, even where this undermines the wider transformative potential of the collective whole (Clark and Wallace, 2015). *Multidisciplinary* research involves researchers from multiple disciplines working together additively on common problems (Klein, 1996), in contrast to interdisciplinary or transdisciplinary approaches that involve substantive integration of norms and values (Hansson, 1999; Karlquist, 1999). In multidisciplinary research, individual researchers retain their foundational disciplinary epistemologies and value systems, which we regard as being linked to their 'path impregnation' (Knorr-Cetina, 1981; Clark and Wallace, 2015). Thus we see the challenge of multidisciplinary working as one of effective epistemic coordination, accommodating the various communities' respective norms and values sufficiently to enable collective actions around particular research projects. We argue that this can emerge through shared research processes in which individuals address particular problems that arise around value disjunctures. Studying this as a collective learning process provides insights into the dynamics by which meaningful multidisciplinarity builds up in practice.

Multidisciplinary research and the Grand Challenges. The centrality of multidisciplinary research to solving the Grand Challenges of the twenty-first century is evident in a number of developments in theory and practice. The theoretical argument exists that these Challenges' origins as unintended consequences of late capitalism's complex organisational systems makes these problems multi-causal, with their multifaceted nature demanding many knowledge inputs. Using bibliometrics, Bugge et al. (2016) chart the simultaneous rise of the bioeconomy concept in multiple science fields as a set of parallel epistemologies, each with their own definitions and conceptualisations, i.e., multidisciplinary rather than interdisciplinary or transdisciplinary (Wallace and Rafols, 2014). But this brings its own problems: Lawton and Rudd (2013) highlight that although cognate disciplines interact effectively, epistemic differences may undermine effective multidisciplinarity. A particular problem here is where one epistemology demands that other disciplines accept its epistemic assumptions, a process which may transpose to individual scientists' interactions subconsciously based on how far disciplines are perceived to conform to an ideal-type version of science operating within logical, transparent, reproducible, and replicable paradigms (Fuller, 2002; Biagioli, 2009). This 'epistemic domination' can then frame, shape, or otherwise prioritise those of the dominant field(s) while marginalising the value judgments of the less-ideal-type fields (see for example Greenhalgh et al. (2014)).

These processes are also visible within research funding policies oriented towards solving the Grand Challenges. The European Commission's Horizon 2020 programme shifted from disciplinary orientations towards seven Grand Challenges requiring multidisciplinary consortia, leaving monodisciplinary science research to the European Research Council and national funding agencies (Benneworth et al., 2016). Certain disciplines' representatives, most notably the social sciences and humanities, have expressed concern regarding their epistemic domination by technological disciplines in both funding streams and research content, processes that leave the humanities almost entirely absent (Else, 2013; Greenhalgh, 2013;

Lee, 2013). H2020's multidisciplinary approach framed the humanities' role as understanding human responses to new technological interventions, rather than allowing humanities researchers the freedom to define their own 'good' research questions within particular problem domains.

Olmos-Peñuela et al. (2014) highlight a number of ways in which humanities, and to a lesser degree social sciences, systematically deviate from the norms of the technological disciplines: they are hermeneutic rather than experimental; they provide understanding rather than allowing predictions; and are intensive and unique rather than extensive and comparable. This raises the risk that some researchers working in multidisciplinary teams may experience the imposition of exogenous value judgments on their choices, thus undermining the value of their multidisciplinary research findings within their own disciplinary community, and disincentivising these marginalised researchers to persist with this and future multidisciplinary research. We therefore frame the policy challenge in encouraging multidisciplinary working as finding optimal ways to avoid this unselfconscious epistemic domination around key scientific practices (such as setting research questions) in ways that lead multidisciplinary teams to internalise the research values of technological over SSH disciplines.

Understanding collective social learning: a Community of Practice approach. The everyday business of science involves scientists undertaking micro-practices such as research question formulation and project planning and execution, while continually tempering their behaviour against their anticipation of how others will judge their practice. Individuals internalise particular disciplinary norms through academic training (e.g. the Ph. D.), leading to path impregnation (Knorr-Cetina, 1981), aggregated in what Kuhn described as paradigms that provide ways to channel individual thinking in collective directions (Kuhn, 1962). Successful and sustainable *multidisciplinary* research project participation requires participants to make judgments according to norms determined within at least two different communities: the immediate community of the research project itself; and the wider epistemic community of their 'disciplinary tribe' (Haas, 1992; Becher and Trowler, 2001). Scientists anticipate their wider epistemic community's judgments based on their past experiences of scientific responses (e.g. whether journals accept their papers, whether projects are funded). In the case of an immediate research community undertaking a multidisciplinary project, the issue of what constitutes good scientific practices is negotiated between team members.

Successful multidisciplinary research therefore requires finding stable common ground between these two kinds of value judgment around particular micro-practices (setting questions that fit with the norms of the team and the individual's wider disciplinary community). Conversely, tensions may arise when project decisions fitting with some epistemic norms are regarded as illegitimate by other team members. Individual scientists must negotiate this to find legitimate practices that all accept in order to undertake multidisciplinary research collaborations. We claim that the dynamics of finding this stable common ground within a multidisciplinary team (working together to identify and agree upon common research activities) represent social learning processes, and we propose to conceptualise them using the Communities of Practice (CoP) theory. Although first proposed by Lave and Wenger (1991; Wenger, 1998) to understand how insurance clerks operatives take routine but complicated decisions, it has more latterly been expanded to deal with how heterogeneous knowledge communities cohere in a productive way (Gertner et al., 2011). The key determinant for Gertner et al. is balancing competing demands for what constitutes valid knowledge and knowledge-creation practices. They identify the roles played by what they term 'boundary spanners' in encouraging negotiations in which new shared norms of knowledge validity emerge. We argue that this property is also useful for understanding the extent to which project teams are able to *build new shared norms*—the policy-maker goal for these new funding instruments—that allow partners from different epistemic communities to build shared knowledge.

Wenger (1998) highlights three features characterising CoPs: mutual engagement; joint enterprise; and shared repertoires (see also Bucholski and Benneworth, 2017). Mutual engagement involves opportunities for individuals to interact with other individuals' problem-solving; joint enterprise involves a common functional goal to which all participants are working; while shared repertoires are independent social practices and activities into which meaning and knowledge are encoded. We transpose this heuristic to characterise an ideal-type multidisciplinary community of practice based around a single research project (Table 1).

Methodology and overview of case study

Research methodology. In this paper we address our operational research question of whether multidisciplinary communities can build up shared local value frames to coordinate common scientific activities. Multidisciplinarity is a relatively well understood category (Klein, 2010), but much less is known about processes of transition, where established (path-impregnated) disciplinary researchers seek to adopt new ways of working to accommodate multidisciplinarity ('adopting multidisciplinarity'). Following the turn to practice in science and technology studies (Soler et al., 2014) we focus specifically on this issue of changing practices as reflecting changes in individual scientists' value judgments and identities. We therefore seek to create valid knowledge regarding how scientists adopted multidisciplinary research micro-practices while sustaining their own disciplinary identities.

We studied a set of scientific project communities emerging from a new policy intervention (the Idélab sandpit event, cf. 'Introduction to the Idélab programme' below), where we argue it may be possible to observe the processes of adopting

Table 1 Key Community of Practice repertoire manifestations in emerging multidisciplinary project teams

CoP repertoire	
Mutual engagement	Regular contacts between the project partners in which they attempt to exercise collective influence to integrate the activities of individual research teams, developing unselfconscious shared scientific identity
Joint enterprise	Sincere attempt to run an integrated scientific project regarded as legitimate within the individual researchers' respective scientific paradigms, internalised within project tools and technologies
Shared repertoires	The emergence of a narrative case history regarding past scientific judgments within the project: as collaborations become longer in their duration, discussions of legitimacy or desirability become less rooted in epistemic judgments and more in what was regarded as legitimate in prior discussions

Source: authors' own design based on Wenger (1998)

multidisciplinarity. Because these processes are not yet rigorously operationally defined, our research is therefore explicitly exploratory, seeking to identify meaningful categories applicable in these situations, the relationships between these categories, and the dynamics of their interrelation processes. We perform this analysis informed by our underpinning theoretical framework that provides a heuristic structure to guide our search without completely determining our search's direction, which retains its constitution through the empirical situation (cf. Latour, 1996). In our heuristic structure the three Community of Practice repertoires may allow scientists to produce satisfactory compromises between the value sets of the discipline and of the group. This is a hermeneutical case study, and we seek to create knowledge about the particular situation of the Idélab to subsequently draw more inferential suggestions about the directions of future exploratory, deductive research.

We use the Community of Practice approach (cf. 'Understanding collective social learning: a Community of Practice approach' above) to structure a thick description (cf. Geertz, 1994) of reported and observed activities around the four primary project groups (our work was funded by a fifth project from the 2014 Idélab, and we attended a number of inter-project meetings and co-organised a programme seminar on multidisciplinarity). In performing this structuring, we analysed our texts by firstly flagging key concepts and secondly by drawing out statements and implications (see the section 'Idélab creating virtual Communities of Practice?, below). On this basis we propose a stylised description of the objects, interrelations, and processes observed, and compare this to our proposed CoP model (cf. 'Steering scientists towards multidisciplinary social learning practices', below). Our data is drawn from a series of 12 structured conversations (henceforth referred to as interviews) with participants who were active in these project groups, of which ten had attended the initial 2014 Idélab event, along with participant observation during the programme sessions.[1] Slightly less than half of these conversations were with participants from a single project team (hereafter referred to as project A) because in the course of our research, they collectively as a team agreed a major change of project direction resulting directly from the participation of researchers from multiple disciplines, while with the other projects, we were aware that after fewer conversations we were already starting to receive repeated findings. We acknowledge our interview sample was by necessity a positive selection of researchers already sympathetic to multidisciplinarity, having applied for and participated in an explicitly multidisciplinary process of their own free will. We nevertheless contend that this does not undermine our research's validity because we are not attempting to make general statements, but rather to nuance and extend a conceptual framework for understanding adopting multidisciplinary research practices.[2]

We also make explicit here our approach's limitations, those that are inherent to any exploratory research lacking a validated conceptual model which would permit deductive or extensive research methods. We are aiming to identify processes that might exist, and to characterise those identified processes in terms of their dynamics and interrelationships in order to subsequently reflect upon and nuance our starting heuristic. We acknowledge that we are not making claims about the frequency with which these activities or processes occur outside our case study, nor do we wish to make totalising claims about the role that multidisciplinary research plays in solving the Grand Challenges. Rather, we limit ourselves to refining understanding of the development of individual scientists' attitudes and ways of working within projects leading to multidisciplinary collaborations, both as the basis for further scientific study as well as for better targeted science policy.

Introduction to the Idélab programme. In this paper we consider the Idélab programme introduced by the Research Council of Norway (RCN), specifically chosen—based on the 'sandpit' idea—to drive change within research practices. The RCN is an important actor in Norway's science system, being responsible for awarding the majority of competitive research funding. The Idélab initiative emerged from an independent review of RCN, following which it decided to become more innovative in its funding methods.

> Recent evaluations of the Research Council have challenged us to play a greater role in promoting activities that generate more groundbreaking research. The Idélab method will cultivate radical projects that cross disciplines and subject areas in new ways. (Norges Forskningsråd, 2013)

The 'sandpit' method had been trialled by the UK's Economic and Social Research Council, and it was a UK-based team that led the first Idélab, a sandpit event which took place in Oslo in January 2014 with the specific desired outcome of funding multidisciplinary research projects that would contribute to a zero-emissions society.

> We had started thinking about finding new ways of addressing social challenges. Then we were informed about the sandpit approach from the ESRC. One of the roles of the Research Council [of Norway] is to be an agent of change. *The inspiration was: how do we change practices with funding research with this change-agent role in mind?* So we decided to try the sandpit method. [RCN interviewee, emphasis added]

The first Idélab was thus from the outset geared towards the generation of multidisciplinary research projects which, if selected on the final day of the week-long event, would be guaranteed RCN funding. The call for applications announced a total of NOK30m (c. €2.8 m) available, subject to the condition that researchers 'submit a full application by the deadline and there is nothing else that dictates otherwise' (Norges Forskningsråd, 2013). Funds were provided by three RCN funding streams—biotechnology, nanotechnology, and information and communications technologies (ICT)—while the food and bio-based industry department agreed to fund projects within its field of interest.[3]

Potential delegates applied by completing a short online application form (in English, the language of the event). Over 200 researchers applied, with backgrounds from the natural sciences, technology, social sciences, and humanities. One hundred and fifty-five applications met the funding scheme's eligibility criteria, and of these RCN selected 30 participants to work with a team of eight mentors and two co-ordinators. RCN funded participants' accommodation and subsistence costs, and individual institutions paid travel costs. The sandpit lasted a complete working week, with delegates arriving and mingling on a Sunday evening at a carbon-neutral conference venue outside Oslo; the event finished the following Friday lunchtime, after the announcement of the successful projects to be funded. The first two days involved brainstorming and thinking around the theme of the zero-emissions society; on the Wednesday and Thursday these ideas were gradually shaped into project proposals with associated teams. These were submitted in written form to the mentors late on Thursday evening, presented orally on Friday, and the event closed with mentors announcing the four 'winners'. Four principal projects were funded for 3 years, the budget having been increased to NOK40m during the week, alongside a fifth, smaller, project to follow the others and reflect on their

multidisciplinary nature for their duration. It is findings from this fifth project that are presented in this paper.

Idélab creating virtual Communities of Practice?

At the end of the week of the Idélab, delegates from the five funded projects departed with high hopes for the future. After three years, the projects fell into two camps; the interviewees from three projects clearly felt that their projects were as successful as could realistically have been hoped on that snowy January Friday in 2014: they achieved their goals, produced scientifically useful work, and formed meaningful multidisciplinary collaborations which they expected to continue in some form even after the funding period (projects A, B, and E). Interviewees from the two other projects were noticeably less satisfied with their projects (projects C and D). Based on our interview analysis, we identified three kinds of activity within projects which represented sites where multidisciplinary research practices might be being adopted. Firstly, some interviewees provided examples where the teams had deliberately made efforts to create project-specific languages to allow participants from various communities to meaningfully and jointly participate in collective research practices. Secondly, we were told of two examples where collective decisions about research focus in these primarily technological projects were profoundly influenced by inputs from SSH team members and work packages. Thirdly, a number of researchers related the negative experience of learning during the course of the Idélab sandpit event of RCN's requirements for the projects, namely that only those proposals that corresponded to the funders' three domain areas were welcome. More information is presented on each of these three activities below, and then in the section 'Steering scientists towards multidisciplinary social learning practices' we return to the initial heuristic and seek to nuance it based on these findings.

The language of collaboration and multidisciplinary research. The Idélab projects shared the common characteristic of being multi-epistemic; most projects had a primary technology focus along with active engagement from social science researchers. Most projects were divided into primarily (mono-)disciplinary work packages, with project meetings where different work packages reported progress. Our interviews suggested that a substantial obstacle facing the projects was how results—particularly interim or incomplete results, and failures—could be presented to project members in a way that everyone understood and found useful. For most projects, this involved individual researchers avoiding discipline-specific details when reporting to the group, instead focusing on what was essential to the whole project. Some went further, however:

> If we go into the details other people just stop listening. […] People won't understand. *But if I do basic storytelling*, or more interesting or more general things, then people can follow what I'm saying. But too many details and they will just be lost. [Researcher A3, emphasis added.]

> I maybe don't use terms for things that we have [in my scientific community]; I use some kind of layman description. Even though you can describe something with only two words, if they are words they [other project members] have never heard of it's easier not to. […] *I have to think in advance: 'Is this the way I want to explain it?'* [Researcher A5, emphasis added.]

These examples highlight two different strategies applied independently by two researchers from project A. The first researcher explicitly referred to storytelling, presented results as a narrative, with that week's findings related to the wider project's unfolding, making it easier for everyone in the group to grasp, regardless of disciplinary background. The second researcher reported forward-thinking and taking care to think before speaking, being very conscious of the language employed when talking to the group.

Another project approached the group communication problem differently:

> We have had an emphasis in the project that we try to communicate simply to each other; a multidisciplinary project will always have these challenges, there will always be some jargon and you have to learn each other's way of speaking. […] We had a very low threshold for stopping each other to define words, or explain underlying mechanisms behind phenomena or whatever, and I think that has worked pretty well, even if you have to do that several times before it sticks. […] So we have some common language and get familiar with some of the technical terms, but we also had to define a solution base. We wanted to implement the technology, and we had a choice between different scale levels. *So we kind of created a jargon that we are all familiar with that is maybe unusual to someone from the outside. We defined the size of it and don't have to repeat that much any more. We have also created our own jargon in a way, to explore different situations*. [Researcher B1, emphasis added.]

In project B's early stages, the group focused specifically on creating what they referred to as their own 'common language' and 'solution base' providing everyone with certain common mutually comprehensive jargon for meetings. This approach (where the project itself forged its own common terminology) was very focused on the project *community*, rather than relying on *individual* researchers' efforts. As Researcher B1 acknowledged, such internal jargon would not necessarily be understandable to others outside the group setting and therefore using common terminology makes two clear statements. First, it indicated who did or did not belong to that particular project community, and second, it made a distinction between whether a researcher was communicating with fellow community members or with those outside the group (e.g. external stakeholders or discipline peers).

These two examples are thus indicative of projects adopting the CoP feature of a 'shared repertoire'. Project B's word bank contributed to a common case history, which over time allowed project members to build up a knowledge base established as legitimate in prior discussions. With project A, the communication norms established early by the project's members can be understood as helping the emergence of a narrative case history of scientific judgments, which was later associated with a scientific judgment leading to a fundamental change of direction in the group's research project (see also 'Project practices embodying social learning practices', below).

Project practices embodying social learning practices. The principle reason project A became our primary case study was because this project underwent, in its first year, a major change of direction resulting directly from its multidisciplinary nature. The project group stopped one (technical) work package's activities following input from the 'social impact' work package. This decision was reached involving extensive social interactions, bringing consequences for all group participants. One interviewee recalled:

> I didn't have any opinion on it when we started. I didn't know enough about it. I never really opined anything firm

Table 2 Summary of the principal Communities of Practice features displayed in the five projects funded following the 2014 Idélab

Project	Communities of Practice Features	Examples from interviewees	Further multidisciplinary work envisaged?
A	Shared repertoire	Storytelling/awareness of language and audience when reporting results	Yes
	Mutual engagement	Group decision to terminate one work package following social science input and individual reflection	
	Joint enterprise	Clear and consistent sense of all work packages contributing to the project's common goal	
B	Shared repertoire	Defining technical terms; establishment of common jargon	Yes
	Joint enterprise	The shared repertoire served the project's technological and scientific goals	
	Mutual engagement	A clear sense of project identity	
C	Lack of joint enterprise	Work packages operating independently	Not with this team
	Lack of mutual engagement	Perceived leadership problems, lack of shared project identity	
	Lack of shared repertoire	Perceived leadership problems, lack of shared project identity	
D	Lack of shared repertoire	Communication problems	No
	Lack of mutual engagement	Experience of 'barriers' between disciplines rather than a shared project goal	
E	Shared repertoire	Reflection continued throughout the project and was perceived as a strength	Yes
	Mutual engagement	Regular discussions of impact and ethics related to the project such that it became internalised in individual researchers' everyday scientific practices both in the project and in their own disciplines	
	Joint enterprise	Group reflection helped to build trust and mutual understanding	

> on the issue. So the conclusion came as a result of the process, and it did not come as a result of somebody shouting and screaming. *It was a good experience, and probably the right decision*. But if you had asked me before, about two years ago, maybe I would have said something like, 'well it can't hurt to do research so that we generate knowledge and then maybe it will be useful in the future', something like that. But now we concluded to stop researching that area, and *now I think I see it more as the right decision* to not waste resources on something for which the actual usefulness is questionable, without actually concluding that it is probably not useful, but it is so questionable and I cannot resolve the question, I can only note that it is debated and probably the majority would conclude that it is not useful so let's not waste resources. This is my view now and it is different from when I started, for I did not have strong opinions. *I see it as a good thing, and there are probably other projects for which similar processes would be useful*. This particular work package not only brought up things about law and what the public would think about such large-scale operations, but also to my (small) surprise that it isn't sure at all whether if you still went ahead with it, it would remove carbon from the cycle as intended. So it revealed a lot of different parties there. *That was illuminating*. [Researcher A1, emphases added.]

This quotation reveals several learning practices, involving the public, collective governance, and individual reflection and its impact on technological research. First, research involving the general public revealed the public perception of the work undertaken. Second, the group decision to stop work on one area was taken collectively only after all those involved had given input. Third, the researcher's individual reflection acknowledged a distinct change of personal stance on the issue: Researcher A1's initial opinion that 'it can't hurt to do research' swung around to a perspective that weighed the societal usefulness of the research against the resources they would have expended on it—this was as a result of input regarding the societal impact of the proposed work. Researcher A1 also expressed surprise that the societal impact research had also cast doubt on the technological research —had this work package continued, the project's overall goal (and that of the first Idélab, lowering carbon emissions) might have been compromised. Finally, in their reflections the interviewee viewed the whole process as positive, and applicable to other research areas.

We point to the quotation above as an example of a natural science researcher reflecting on the positive outcome of the decision for the project, and on what they as an individual had learnt from how work in a different discipline (the social sciences) directly affected work in a third discipline (another natural science). This appears to be a relatively clear-cut example of all three elements of a CoP in action (cf the section 'Understanding collective social learning: a Community of Practice approach', above, and Tables 1 and 2): mutual engagement in which project members exercised their collective influences on a group decision; joint enterprise where all project members contributed to the adjusting of the common goal that nevertheless remained legitimate in their own disciplines as well as the project as a whole; and shared repertoires of communication (as discussed above).

A final example from a third project, project E, shows how the adoption of communication strategies brought to the group from the SSH researchers involved directly increased reflection and 'trust':

> It turned out that we would have a couple of hours each month to talk about ethics and the future impact of the project and how we do science. And what we found is that this has been a great strength in the project all the time. *It has forced us to really think about this all the time, and these are things we wouldn't have thought about otherwise*. It builds a lot of trust between people, it makes it easier to ask questions, with these people who clearly don't know physics and chemistry makes us make sure that everyone understands. *Very often you cannot understand what others are doing and you have to trust that they are making the right decisions towards a very well-defined common goal*. So even if we are not experts in each others' fields we can trust that we are heading in the same direction. [Researcher E1, emphases added]

It can be seen from this quotation that the interviewee unintentionally refers to all three features of CoPs. The continuous group reflection on ethical matters that 'we wouldn't have thought about otherwise' shows both mutual engagement (developing scientific identity as a group) and joint enterprise (the reflection technique came to be considered legitimate by all and was thus internalised within the project). That the reflections continued throughout the project and were considered a 'strength' shows that the project witnessed a development of a shared repertoire based on prior discussions and understandings.

These projects witnessed similar patterns of social learning experience, which are summarised in Table 2. While the results of one had a greater influence on the project's final outcomes than the others, they all shared an increased reflection and integration of societal concerns into individual project members' scientific practices. This both served to hold these multidisciplinary project teams together, and facilitated the development of novel research practices both on the individual level and within the wider project communities. A summary of the features associated with the adoption or limitation of multidisciplinary practices across all the projects is summarised in Table 2, and discussed further in the next section.

'Antisocial learning': compliance practices in Idélab. Both the Idélab sandpit and the individual projects experienced problems and tensions derived from the activities' multi-paradigmatic nature. One of the earliest metaphorical hiccoughs, with lasting repercussions, occurred in the Idélab sandpit itself when, relatively late in the week, some of the groups that had formed to work on project proposals were told they had no chance of receiving funding because their ideas did not align with at least two of the three participating funding streams (biotechnology, nanotechnology, and ICT). One researcher recalled it thus:

> With [another delegate] I was developing an idea, […] it was a really cool project. But as time passed I realised it wasn't what the mentors wanted; they wanted more stuff related to the themes of the Idélab, as far as I understood. And that was a bummer because we had invested quite a lot of time into it. So we had to think of something else and there was no time to start on something new so we joined in with an existing idea. […] I sort of became pushed into this group by the mentors there, and I got the feeling that the leaders of that project initially thought that it was unnecessary for me to be part of it. […] I always felt from the start that my part was on the side, not a full member. […] So I was a bit disappointed. [Researcher A2]

At the Idélab RCN acknowledged and apologised for this oversight regarding requirements, and backed up their apology by providing the NOK10m extra funding.[4] With four of the Idélab participant interviewees spontaneously recalling that episode, it is clear that even three years later they attached a considerable degree of importance to that requirement.[5] The episode functioned to drive a forced compliance with the goals of a small number of RCN funding streams, despite the Idélab purporting to emphasise creativity and to encourage individual researchers to step out of their comfort zones. This restriction, whether explicit or implicit, worked against building the collaboration and openness associated with a community feeling among researchers collaborating on multidisciplinary projects. Indeed, researcher A2 learned from the experience that before they are able to use their expertise to work together with other researchers to save the world in the future, they will first have to 'look for the money':

> If I ever take part in another Idélab I will be less open-minded, and more targeted towards what the funders actually want, which is unfortunate, but that's how it is unless the Research Council become more open-minded themselves. That remains to be seen. The goals should have been communicated more clearly from the start. I feel like I wasted 2 days there on a project that was a no-goer, and got punished double because not only can you not continue with what you wanted to do, you cannot start something new. You have to jump into an existing project and then you get down-prioritised. [Researcher A2]

From our perspective, this represents an interesting finding, because one might sense here the sentiment that researcher A2 was peripheral to the project A community, despite being a technological researcher; in we observed above that the SSH research team in this project had become 'core' in the project community, as evinced by the radical change in project direction. We regard this not necessarily as a demonstration of 'failure' (in whatever sense), but conversely a suggestion that the project team was successfully multidisciplinary: at the heart of this project was a meeting of two natural sciences (chemistry and biology), complemented by three further disciplines (physics, social sciences, and ICT). Researcher A2's apparent disappointment can be understood here to be more on the personal level than about project A itself: during the sandpit event they had felt forced to abandon hopes of co-leadership of a different multidisciplinary project because it did not meet the (then inadequately expressed) criteria of the funders. Researcher A2 had then chosen to accept a more peripheral role in a project that was already well into the planning stages. That the receiving project and its team—which would go on to receive funding (project A)—were flexible enough to adapt to the arrival of new researchers late in the sandpit event witnesses this project's inherently multidisciplinary nature.

Steering scientists towards multidisciplinary social learning practices

The three kinds of Community of Practice activities provide a means to reflect on the initial starting heuristic and ultimately to provide an answer to our operational research question, namely: can multidisciplinary communities build up shared local value frames to coordinate common scientific activities? In this section, we firstly explore the features of the micro-research practices (drawn together in Table 2 above) that were associated with the successful adoption of multidisciplinary research values, and then consider the tensions that stood in the way of the emergence of multidisciplinary research values. We then reflect upon the value of these new funding approaches in stimulating disciplinary researchers to consider adopting multidisciplinary research practices based on shared sets of research values.

Research Council funding criteria stimulating social learning practices?. Projects A, B, and E can be interpreted as offering examples of the three features of Communities of Practice (mutual engagement, joint enterprise, and shared repertories). These were researchers who were in regular contact with each other, who understood the mutual legitimacy of the project's aims across the disciplines involved, and who shared means of communication both inside and outside the projects. RCN identified that the sandpit approach had driven a degree of change in behaviours, and has indeed since organised a further three Idélabs in order to generate new multidisciplinary collaborations around other research themes (Norges Forskningsråd, 2017). The importance of multidisciplinarity and social learning was already implicit in the first presentation of the Idélab to the Norwegian public in 2013:

> A main feature of an Idélab event is that the participants are challenged in an interactive process with researchers from subject areas with whom they would not typically collaborate. The researchers are brought together in cross-disciplinary groups for a 5-day workshop. During this period they will develop ideas into concrete project proposals with advice from highly qualified external mentors and a leader who has overall responsibility for the entire gathering. (Norges Forskningsråd, 2013)

This same point was taken up and developed in our interview:

> One of the very important impacts might be not only the projects funded, but also the new ways of networking. We know that people are working together afterwards, not only in directly funded projects, but also in planning future projects. So that may be an important outcome. […] I realise that when you've got your funding, there is a danger that you more-or-less go back to your old practices, and earlier methodologies are not evolving into ways of reflecting differently about your research… In some ways it changes you, but it's maybe not dramatic. Maybe it takes more time to change practices—more than just one project, one practice. But the article [Røyne et al., 2017] points out that it's not dramatically changing the way they work, but there are new ways of thinking about things, reflecting on ethics, crossing borders in new ways between technologists and social scientists, and the way of working from different perspectives. [RCN]

The Research Council of Norway interviewee had observed the individual researcher's (or researchers') involvement in social learning practices and the progressive nature of research as a knowledge-creation activity. The 'new ways of thinking' were not necessarily dramatic, but the RCN interviewee argued that they had perceived the start of a 'ripple effect'. This might be characterised as taking part in an Idélab and an attendant multidisciplinary project as an experience that stays with individuals; the corollary of that would be that those researchers would then pass the experience on to their students, postdocs, colleagues, and research partners. This second-order effect was suggested in the interviews with the two, more junior, researchers recruited to project A after the Idélab: among all the interviews, their voices were among the most open and welcoming supporters of this kind of work. Indeed, the RCN interviewee suggested that younger researchers could be the strongest drivers of the changes the Council envisages:

> It's important to maybe start with using most energy on new, young researchers who are open for new understandings and doing things differently, rather than more experienced researchers whose mindsets can be difficult to change. Focusing on the younger generations is important. They are the future. [RCN]

Nevertheless, while the interviewees were broadly supportive of the Idélab and the way of working it engendered, its strongest critic—indeed, the only interviewee who did not consider the process to be at the very least a successful experiment—was among the most junior in their career. Likewise, the researchers who showed the most apparent and deep-rooted changes to their individual practices were the most senior and/or experienced. This precludes suggesting any kind of division by seniority or experience and highlights that the success of projects involving multidisciplinary social learning practices depended to a significant extent upon individual researchers, who, given the application process for the Idélab, could be expected to be open to such kinds of learning processes. The RCN interviewee reiterated this in reflecting on the involvement of SSH researchers in the Idélab-funded projects:

> It's all about mentality. They [researchers from social sciences and/or humanities] have to learn the technology and understand it, that is way beyond their own disciplinary practices, and some are not interested at all. Some are trying to say that this is not the way to develop competencies in the social sciences and humanities, and in fact it drains them, because they have to take part in research questions that are far from them and are not the focus of the research. There are a lot of social science and humanities researchers who are quite sceptical of being involved in such projects. They want to do research within their own understandings of the discipline, which I can understand, but others are very keen to be pushed out of their comfort zone. Some like it, some don't. The same is true for other disciplines, sometimes they don't want to face the real world, or the interlinkages or complexities. But if you are going to address social science in tech research, then you have to go out of your comfort zones. […] You're not going to solve big problems within disciplinary boundaries—you have to cross them. That is the intention behind Idélab, to get people out of their comfort zones, and expand and use their competencies in different ways. [RCN]

With change being individual, and the adoption of multi-disciplinary research practices depending on individuals, the emergence of multidisciplinary practices appears to be slow. Additionally, the awarding of RCN funding via Idélabs represents an intervention that in the context of the Research Council of Norway as a whole involves research projects that were in the first instance rather marginal, something of which RCN were well aware:[6]

> We are looking at how to make sure, after funding, that the projects are really staying in line with the aims of the Idélab, and having the resources to follow up is critical. We can do much better when it comes to following up the projects than we do currently. It's very easy to fall back into old research practices when you are no longer at the Idélab. It's difficult to be in that kind of mental change, pushing yourself to do things differently, when it comes to the actual practice afterwards. How do we help people stay out of their comfort zones? It's not easy to do things in different ways. When it's just one project trying to do things differently, and you have other things to do as well, there are not perhaps enough resources on just this one project to step out of your practices and change your methodologies. That's really challenging for all the participants, to be able to change practices, not only for a short time, but changing your research on other projects too. Changing practices is not easy. [RCN]

There was equally an awareness that these attempts to drive change were being promoted in an environment where publications, metrics, and rankings were supremely important (not least because Norway has a research funding quantum that incentivises publication in prestigious outlets). This led to a situation where the RCN interviewee—and, by inference, the organisation they represented—argued that they believed that some things were more important than a project's measurable outcomes:

> What we are trying to do, and to some extent have succeeded in doing, is to focus more on the impact of research, and addressing social challenges. These are very complex, and we need research practices to change. We

> can't do it in the old ways. *It's not only quality that counts—quality in the academic sense—but re-defining how quality is understood when it comes to addressing and solving social challenges*. Being part of that initiative, to try to move research into new fields of understanding and working—that's important, and I'm quite proud to be one of the people in the Research Council who are challenging traditional practices. [RCN, emphasis added]

Although this is refreshing given contemporary policy emphasis on metrics and rankings, with Idélabs representing just a small part of RCN's funding processes, the drive towards pluralism in research funding is moving forward very slowly. However, the success of the Idélabs seems to have opened a discursive opportunity within RCN where multidisciplinary practices were not simply dismissed out of hand:

> I think we need a multitude of ways of funding research. But trying to see the interlinkages between different kinds of research, and getting people to work together, these are the way forward. Researchers need to focus more and more on understanding complexity. You have to develop multi- and transdisciplinary practices all over the place. I think it's important that people can also focus on very narrow projects and that's important within disciplinary boundaries, but being only there is not the way forward. [RCN]

A first-cut analysis of the underlying tensions. The interviews also highlighted various characteristics that undermined developing project-based learning communities with shared value sets. A first tension (more easily overcome in some projects than others) was that project leaders were required to understand and appreciate which skills were necessary in participants from other disciplinary areas, something that appeared to require flexibility, openness, and reflexivity. This was in particular necessary to deal with recruiting and maintaining the project team regardless of events in individual researchers' professional and personal lives, covering individuals undergoing job changes, career shifts, along with temporary and/or permanent departures from science. Ensuring that these evolutions allowed sufficient skillsets to be retained in all teams required leaders to have a strong grasp of the project's shared goals. Both researchers interviewed from project C strongly suggested that the project's leadership was at least partly responsible for their lack of success; one expressed it thus:

> But with [leader] as a project leader it just did not succeed. I proposed reducing the amount that [leader] did… Three postdocs plus reviews, but [leader] was the coordinator, the most important part. This was not what was suggested in the beginning, with four equal parts. And [leader] was mad about that.. […] I'm not sure how it was organised. [Leader]'s postdocs were part-time, so [leader] still has money left to do something. The plan was to have one postdoc each and have them collaborate with each other. But that didn't work out. It was not a good group altogether. That's how it worked out. [Researcher C2]

This suggests that the multidisciplinary project community experienced issues in multi-paradigmatic working, namely minds just not quite meeting, or not communicating well within the group. Relating this to our model, we see a lack of mutual engagement (irregular contact, unstable project membership) and joint enterprise (disciplines worked separately rather than together), together with no real chance to develop a shared repertoire due to communication problems (discussed further below). Researcher C2 proposed to disentangle the teams and reduce one team's resources as a solution, clearly a different solution from project A where thorough discussion allowed for resolution of a fairly existential problem, something potentially far more threatening to the whole project than problems with postdoc recruitment and retention. Researcher D1 noted that the whole process had made them sceptical to the very notion of multidisciplinary communications and future collaboration:

> I feel that within my project our different backgrounds made communication a bit difficult. It took way too long for me to understand those barriers… I'm—hopefully—much more sceptical about collaborating with people I don't know. In general I've become more of a sceptic.
>
> [Interviewer: Of what?]
>
> Of working with different fields, different people. I used to be much more happy-go-lucky. But in the last three years I've experienced lots of other stuff. I'm three years older, I'm less adventurous. I've become much more focused on cooperating with the right people. I will… think more thoroughly before entering into any [future] project. That might also be age!

This can be compared with the sense of regret articulated by researcher C2 that there had not been more communications within the team:

> The four groups worked separately.
>
> [Interviewer: Is that how you would normally work?]
>
> I wish I had more experience with this! I guess it's often the way it works. We know now what to expect. […] We wanted the postdocs to meet once a month, but we didn't have enough postdocs. We met twice a year as a group and that was interesting. And we always planned what to do together in the project experiment—but now I think there will be no project experiment. I believe that we could have been closer together, and more committed.

The manner of delivery of these two quotations by the researchers illuminates the two researchers' experiences of multidisciplinary working environments. First, the interviewees' short sentences and pauses, and the interviewer's interjections, show that the researchers had some trouble finding the right words (with the caveat they were both aware of their words being recorded and of being interviewed in a second language by a native speaker of that language). Both attempted to leaven their negative perspectives with hints of good-humoured self-deprecation, either with regards to experience or with growing older. Both made clear the existence of communication problems, giving no indication of shared repertoire in these projects: 'groups worked separately' (C2), or there were 'barriers' (D1). This in turn highlights that one-off experiences alone were unlikely to be sufficient to impregnate these researchers with norms and values leading to more multidisciplinary future research practices.

Discussion and conclusion

In this paper, we asked the overall research question of whether new funding approaches can contribute to creating new scientist behaviours towards Challenge-driven research, something we have explored operationally by considering the ways that the changes demanded to micro-practices have changed scientists' expectations and beliefs. Our small sample of researchers had all applied for and attended the first Idélab to be held in Norway (an event that had the clear goal of establishing multidisciplinary projects), or were beneficiaries of funded projects, suggesting that

participants were already sympathetic towards multidisciplinary collaboration. Nevertheless, it is clear that those projects which best realised their multidisciplinary potential (A, B, and E) were those that (by means worked out by the project members themselves) developed what we conceptualised as Communities of Practice and social learning, where the research of individual work packages was valued on an equal footing. This is most particularly visible in our primary case study of project A, where the social science work package not only profoundly affected the project's overall direction, but also prompted personal reflection and change among individual (and non-social-scientist) project members. This apparent greater equality of disciplines among collaborating researchers was very different to the picture sketched by Science Europe in 2014 of the marginalisation and exclusion of particular disciplines. The integration of social learning practices into the observed multidisciplinary projects highlights that it is possible to achieve epistemic equivalence.

This epistemic equivalence occurred in this case even with resources unequally distributed across disciplines and work packages. It also required the project teams to develop ways to feel that their learning trajectories within the project were epistemically legitimate. This suggests that what is important is an ex ante commitment and ex post recognition of the added value brought by multidisciplinary research through social learning. And this ex post recognition in turn lays the basis to encourage future ex ante commitment to more social learning activity, which corresponds to the idea of path impregnation for researchers.

As Table 2 (above) highlights, the projects most successful in developing epistemic equivalence were those that had activities corresponding to the features of Communities of Practice: (a) mutual engagement in core activities such as defining research questions and problem-solving; (b) joint enterprise where all members saw themselves as working towards an agreed common goal that could be legitimate across all the disciplinary paradigms represented; and (c) shared repertoires where the meaning and knowledge generated became encoded and internalised in the individual researchers' working methods. They were moreover project communities where participants were all willing and able to become mutually dependent on each other's varying knowledge and expertise. This interdependence underpinned research producing new knowledge able to respond directly to the climate Grand Challenges. We can therefore conclude that the new funding approaches attempted here (the Idélab sandpit) appear to contribute to changing participating scientific communities' expectations and beliefs, and create new ways of working on Challenge-driven research.

Our other cases point to the persistence of problems that arise in attempts to build epistemic equivalence through funding streams. We posit that one possible reason for this is the 'anti-social' view of those disciplines situating themselves at the peripheries of these scientific research communities. Where researchers within some disciplines doubted their own validity to receive substantive research funding to address practical questions, it was harder to incorporate them into these multidisciplinary research communities (at the same time highlighting the importance of feeling validated in the research contexts). One further apparent issue was a concern that multidisciplinary research was supplemental to disciplinary research, evoking feelings that multidisciplinary research was not contributing to core disciplinary questions. That raises for us the paradox that two dominant science policy discourses, namely solving the Grand Challenges and building an excellent disciplinary science base, appear to be irreconcilable.

Our research suggests that it is legitimate to argue that it is not just individual researchers and projects who need to adapt social learning practices for scientific research, but also funding agencies, both nationally and internationally. The Norwegian Idélab funding constitutes only a small part of the country's overall funding strategy, and has never really been regarded as part of the strategy to drive excellent Norwegian research. The attention it has received further suggests that multidisciplinary work is an adjunct to excellent research. Indeed, publications in widely-read non-scientific journals (such as Røyne et al., 2017), together with attention from high levels of government and the mainstream media (the Norwegian minister for industry, Monica Mæland, opened the most recent Idélab in June 2017, as reported in Blich Bakken, 2017), are serving to generate interest in multidisciplinary work from various different angles.

While we acknowledge the need for many ways of funding research, and for different types of research, we argue that the social learning practices we have outlined here among individual projects, researchers, and one national funding system, are also required elsewhere. No amount of sandpits will ever solve the Grand Challenges, nor can multidisciplinary research exist without strong core disciplinary research communities. Nevertheless, an increased awareness of the potential of multidisciplinary working under conditions of epistemic equivalence, together with an acknowledgement (financial as well as theoretical) of this equivalence, might in time generate the kind of changes on a grander scale that as we have seen here are possible on the small scale.

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Notes

1 More detail on the case study method explaining the interviews and document gathering is provided later in this section.
2 The interviewees (including RCN) were not made explicitly aware of the conceptual categories of the CoP model to avoid a weak reading-off approach—our interviews focused explicitly on collaborative and interactive behaviours and practices over the duration of the research projects.
3 While it may seem obvious in hindsight that the provision of resources from this rather small pool (when considered alongside RCN's high number of funding streams) would have a profound effect on the kind of projects that were to be funded, this did not become clear to participants until rather late in the first Idélab. This is a situation that has been clarified in subsequent Idélabs. To date there have been four, with the latter two being more industry-focused and lasting only 3 days. For more details see Norges Forskningsråd, 2017.
4 This kind of misunderstanding has not recurred at subsequent Idélabs, where requirements for receiving funding are made explicit from a much earlier stage.
5 As this study focuses only on funded projects, and those delegates who did not receive funding were even more directly adversely affected by this misunderstanding, we can presume that a significant number must recall the 2014 Idélab in this light.
6 There was an element of progression from the observed Idélab in that three of the project teams (A, B, and E) were all involved in seeking additional 'mainstream' RCN funding, suggesting that the multidisciplinary work born from the Idélab was sufficiently coherent to then find funding elsewhere, and hinting of a potential reshaping of the funding landscape towards more multidisciplinary research activities.

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Data availability

The datasets generated during and analysed in the current study are not publicly available as they are personal interviews governed by a consent form, but anonymised transcripts are available from the corresponding author on reasonable request.

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Additional information

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