Agility in Transdisciplinary Research: Lessons Learnt from a Research Sprint on Digital Technologies and Flood Risk Management

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ABSTRACT

Environmental challenges demand radically transdisciplinary approaches in order to respond to their complexity. Whilst transdisciplinarity has become a buzzword, less attention has been given to approaches that genuinely transcend disciplinary boundaries and support work within multifaceted and volatile research environments. This paper examines the adaptation of an existing transdisciplinary research management framework and extracts lessons learnt from its adoption in a one-year research sprint exploring the role of digital technologies in flood risk management (the flood sprint). Drawing on interviews (N=14) with the flood sprint core university team (including researchers and the project administrator) and partners, we present the opportunities and challenges of this approach. Specifically, we find that whilst the approach fostered meaningful relationships and knowledge building between the researchers and the partners, challenges were experienced within the research team around internal collaboration and the pressures of the sprint cycle. The balance between rapid prototyping and longevity was also a challenge.

CCS CONCEPTS

• General and reference ~Cross-computing tools and techniques

KEYWORDS

Flood risk management, wicked problems, transdisciplinary research, agile methodology, research sprints

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1 Introduction

Environmental challenges demand transdisciplinary approaches in order to fully respond to their complexity and uncertainty, and to allow for the exploration of possible interventions and solutions [1] [2]. Within the environmental domain, transdisciplinarity is "increasingly common, motivated by the intellectual demands of dealing with complex interrelated issues at the food, water, energy, and environment nexus" [1]. Mattor et al. define transdisciplinarity as spanning disciplinary boundaries, being problem-focused, and integrating knowledge "through mutual learning to create new analytical frameworks and approaches for conducting research and improving society's ability to address complex problems" [2]. In addition, transdisciplinarity does not just bring different disciplines and stakeholders together, but also integrates them, supporting different forms of knowledge production [1].

However, what transdisciplinary ways of working might actually look like in the context of researching environmental 'wicked problems' has been little explored (we define environmental wicked problems as complex problems where there is a high level of scientific uncertainty and where there is no single, optimal solution [3]). This paper responds to this gap by reporting upon the approach taken by a one-year *research sprint* focused on the role of digital technologies in flood risk management. The flood sprint brought together a transdisciplinary research team (including researchers from computer science, environmental science, statistics and arts and design) with flood risk experts from both public (governmental) and private agencies. Given the complexities of the flooding domain and the diverse range of perspectives brought together, there was a need for a research approach that facilitated collaborative transdisciplinary work in a research space defined by uncertainty and complexity.

An existing research management framework named Speedplay offered a source of inspiration [4] [5]. Speedplay is an approach that developed from a programme of community-university partnerships [6] established to gain a ground-up understanding of complex societal problems and jointly identify ways to address them through digital technology. Speedplay did so by drawing on participatory design, action research, and agile development. In the adaptation of Speedplay to the flood sprint, agile was of particular interest as a way of delivering working prototypes regularly and rapidly in partnership with external stakeholders. The flood sprint did not rigidly apply Speedplay as a methodology but embodied its participatory, reflective and agile mindset by adopting four key principles: partnership, reflectiveness, iteration and openness to change.

These four principles were supported by a variety of communication and sharing mechanisms (e.g. workshops and show & tells with external partners) and rapid prototyping. The sprint itself was also a key mechanism, marking the first year of a five-year research programme to explore the role of digital technologies in different environmental domains and challenges. By employing a sprint cycle, the research programme aimed to facilitate intense 'deep-dives' into different knowledge domains and deliver significant research outputs and working prototypes over a shorter timeframe.

The intuition was that the adopted principles and their supporting mechanisms would be beneficial in 1) enabling effective transdisciplinary work; 2) embedding stakeholders into the research process; and 3) facilitating the design, development and implementation of digital prototypes. This paper considers the extent to which these intuitions were confirmed and whether the approach taken offers a useful way forward for transdisciplinary research on environmental challenges.

In order to investigate this, we conducted a series of in-depth, semi-structured interviews with the internal core team, research partners, and other stakeholders (N=14). This paper reports on the findings from this qualitative research and outlines key lessons learnt from applying agile principles in the flood risk management domain. We thematically group lessons learnt around the core four principles adopted in the research sprint (partnership, iteration, openness to change, and reflectiveness) and their supporting mechanisms.

2 Research Domain: Flood Risk Management

A report by the UN in 2015 indicated that over the previous 20 years, 157,000 people had died worldwide as a result of flooding [7]. Within that period, 2.3 billion people were impacted by flooding, which represents 56% of all weather-related disasters. The European Environment Agency has also reported that they anticipate a fivefold increase in flood-related losses by 2050, with a possible 17-fold increase by 2080 [8]. Underpinning these projections is an acknowledgement that, with climate change, we can anticipate a significant increase in extreme weather-related events. This makes the field of flood risk management increasingly critical.

Flood risk management is driven by the goal of reducing the likelihood and/or impact of flooding. As the field has evolved, there is recognition that this is not just a cross-disciplinary pursuit, going beyond engineering and embracing the social context of flooding. There is also a significant move towards understanding and managing risk, for example by consideration of sources through pathways to receptors. Sayers et al. [9] build on these observations and describe an approach to strategic flood risk management that aims to holistically reduce risk to people and communities, economies, ecosystems and cultural heritage/landscape (fig. 1).

Decision-making in flood risk management is increasingly reliant on data, with the availability of data increasing significantly in recent years, for example big data [9]. There are a number of research challenges associated with making sense of this data. For example, the data tends to be highly complex and heterogeneous, with a mix of sources that may be structured or unstructured, quantitative or qualitative, and representing different temporal or spatial scales. Traditionally, flood risk management has relied heavily on hydrological process models and there is an added element that such process understanding must co-exist with and complement the new knowledge emerging from data and data models. This challenge is perhaps best captured by fig. 2, taken from the UK National Flood Resilience Review [10]. The top of this diagram shows an integrated simulation pathway showing linked models from models for 'Global Weather' through to 'Response'. This is a classical chain of process models based on capturing and modelling current scientific understanding of the processes involved. Below that, we see data-driven or statistical models from 'Hydrology' through to 'Response', and this is an alternative way of representing knowledge about flood risk management, derived from data. The key point is that these two perspectives need to be integrated and mutually supportive, but little research exists on the relationship between process models and data models.

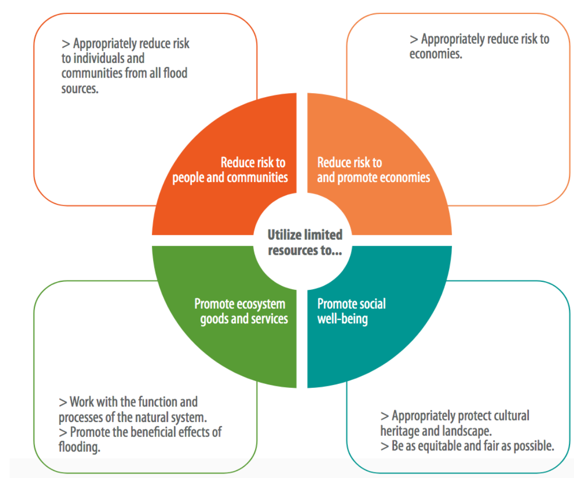

Figure 1: Goals of strategic flood risk management (from [9])

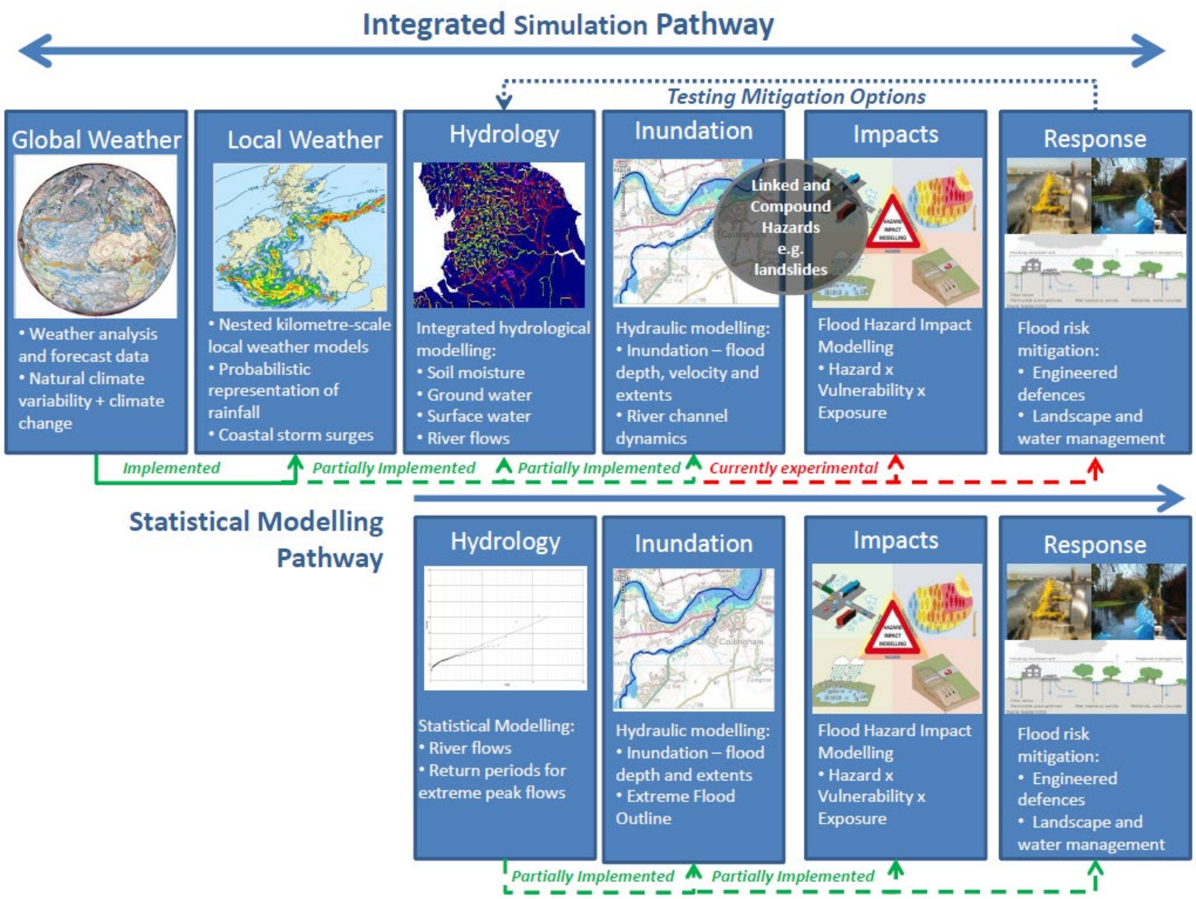

Figure 2: Integrated Simulation Pathway (from [10])

There is therefore a need for transdisciplinary research to rethink flood risk management, decision-making, and sense-making in this increasingly data-driven context. This provided the background and motivation for the flood sprint as discussed in this paper.

3 Related Work

'Wicked' problems necessitate different ways of doing research, and mechanisms of enabling and managing relationships across disciplines and sectors [11] [12]. However, there is little research that considers what this might look like in practice, and what kind of approaches might be helpful. This section highlights the contributions of a small body of work that considers how to enable transdisciplinary research, before turning to accounts of the use of agile as a research methodology.

3.1 Approaches for Transdisciplinary Research

Existing work has acknowledged the challenges that arise from transdisciplinary work. These challenges span the theoretical methodological, and practical [1]. Common challenges identified by Mallor et al. include communication, competing demands (e.g. delivering for stakeholders vs. delivering for funders), and lack of institutional support for such work [2]. There are, however, few studies of how transdisciplinary research might be managed and facilitated. Existing studies range from very specific – for example, how to identify stakeholders for transdisciplinary research [13] – to more general accounts of challenges, principles and best practice [14].

One similar piece of work to our own is an account of the approach taken to manage a transdisciplinary research project on environmental governance [2]. This article offers a series of reflections on having used the notions of 'boundary' settings, concepts, and objects to aid transdisciplinary working. The focus is primarily on the development of a shared language and shared way of understanding and conceptualising the domain, or problem space. By contrast, our paper is also concerned with some of the more practical mechanisms for enabling transdisciplinary work. We also introduce the framework of agility as a series of principles and supporting mechanisms to manage transdisciplinary research.

3.2 Agile as a Research Methodology

Within software development, agile is an approach designed to embrace changing requirements (from the user, client, or customer) by employing short, iterative development cycles that regularly produce working software. It is predicated on close, collaborative work in self-organising teams [15].

A surprisingly small body of research has considered agile as a research methodology. Much of the work that has used agile in research comes from academics that study agile software processes and have adopted this approach in order to align themselves in some ways with their research participants. Agile research methods are, for example, seen as a way to provide research results in a more timely fashion, closer to industry practitioner timescales, but also to ensure constant feedback between researchers and stakeholders through short, iterative research cycles [16] [17]. Within design, agile has also been used as a research approach, through iterative cycles of ethnography: "by viewing failure and breakdown as useful, agile ethnography can help design researchers integrate local knowledge into an iterative design practice" [18].

However, few thorough studies of using agile as a research process exist. One exception [19] reports that agile methods contributed to better coordination and teamwork during an interdisciplinary research project, but specific processes or mechanisms, such as a digital Kanban board to visualise workload and progress, were less popular among the research team. A limitation of this study is that the agile approach was adopted for a very short time, just ten weeks. Sandberg and Crnvokic provide an evaluation of a research project that used Scrum, a particular style of agile, in six-month sprints over a six-year study with industry [20]. This study includes the results of interviews with participating academics and practitioners but provides little in-depth analysis of these results or critical reflection on the methodology. Our paper by contrast aims to be transparent about both the elements that worked well and those that did not work so well.

4 A Transdisciplinary Way of Working

A key inspiration for the experimental, agile and iterative approach that the flood sprint aimed to advance was Speedplay, a research management framework designed for use in "digital and social innovation research" with the aim to "negotiate the challenges of working in partnership with hard-to-reach communities in fast-paced project environments" [4]. It combines principles drawn from agile development, action research, and participatory design. Speedplay is driven, through situated engagement with end-users and stakeholders, to design and develop digital technology prototypes that "embed and support the partnership needs, values and aspirations" [21].

The flood sprint turned to Speedplay, because "we needed a way of carrying out highly exploratory research that's fundamentally cross-disciplinary that involves a range of stakeholders – we needed a way of doing that and standard methodologies just did not look right". Speedplay offered a way of "folding in different disciplines and folding in different stakeholder voices and exploring the unknown", as part of a "cross-disciplinary real-world research programme" (interview with PI).

The flood sprint allowed for the application of Speedplay in a very different domain. Whilst Speedplay's initial usage was in research working with community groups, including vulnerable communities such as homeless people and people with autism, the flood sprint's community of reference was an expert one, consisting of professional environmental scientists in the flood risk management sector.

5 Methodology for Assessing the Flood Sprint Approach

In order to assess the research principles and mechanisms as they were applied and experienced over the course of the flood sprint, the first author was employed to conduct qualitative research. This researcher had no previous involvement in the project and carried out retrospective interviews with a selection of individuals who had been involved in the flood sprint in order to gather their impressions of the year, and their reflections on both the realisation of the research principles and the effectiveness of the supporting mechanisms used.

5.1 Selection of Participants

A purposeful interview sample was selected through consultation between all three authors and the Project Administrator, who managed a lot of the liaisons with partners. This sample was led by two key criteria: firstly, the inclusion of those that had been centrally involved (for example, all members of the internal core team and key external partners); and secondly, a broad range of perspectives, including those who were more peripherally involved. Representatives from all key partner organisations were included in this purposeful sample. As a result of this selection process, fifteen individuals were invited to take part in an interview. Of these, fourteen agreed to participate in the research; there was no response from the other chosen participant. Table 1 provides the notation by which these participants are referred to throughout the paper and summarises their respective roles in the flood sprint. Throughout the following discussion, "core team" is used to refer to the university team, including the PI and project administrator, while "research team" refers to the four senior research associates. The term "external partner" is used to enable easy identification of project partners based at other organisations. However, as subsequent discussion will show, several external partners became integral to, and embedded in, the flood sprint, diminishing any sense of them being 'external'.

Table 1: Interview Participants

Interviewee	Role in flood sprint
R1	Researcher (Senior Research Associate) [core team]
R2	Researcher (Senior Research Associate) [core team]
R3	Researcher (Senior Research Associate) [core team]
R4	Researcher (Senior Research Associate) [core team]
PrA	Project Administrator [core team]
PI	Principal Investigator [core team]
EP1	External Partner (private company)
EP2	External Partner (government agency)
EP3	External Partner (independent intergovernmental organisation)
SC1	Steering Committee member (academic)
SC2	Steering Committee member (academic)
O1	Workshop facilitator
O2	Researcher with experience of using Speedplay
O3	Recipient of Seed Corn funding

5.2 Interview Process

Interviews were semi-structured and followed a four-part structure. Firstly, interviewees were asked about their background and how they came to be involved in the flood sprint. In the case of the research team, questions focused on their previous research experiences, while external partners and steering committee members were asked about their roles and work outside of the flood sprint. Secondly, interviewees were asked to complete a timeline exercise (described below). Thirdly, interviewees were asked a series of questions about their experiences of the flood sprint. These questions were designed to encourage reflection around what worked well in the flood sprint and what worked less well. Interviewees were asked about their general experience, including high- and low-points, before being asked about the agile approach itself. Interview questions about the agile approach included the following:

- The flood sprint took an agile approach. How would you describe this to someone unfamiliar with agile?
- Were you familiar with agile before? If not, what was your immediate response to it?
- How did the flood sprint compare to other research projects you have worked on in terms of the approach taken?

Finally, there was a card sorting exercise (described below). Whilst all interviews followed this four-part structure, space was given to allow for the emergence of other interesting topics and the researcher followed up on various themes that arose through the course of the interviews.

As described above, the interviews were book-ended by two participative exercises. To commence the interview, the researcher asked participants to draw a timeline of the flood sprint. This exercise functioned to jog the memory of participants given that the flood sprint had been the previous year. It also worked as a form of retrospective, an agile process designed to encourage reflection on high- and low-points of a completed sprint cycle [22]. The exercise enabled the participants to map out the year, including their own conceptualisation of the flood sprint's 'shape' and its key milestones, and, following questions and prompts, begin to express their feelings about the experience.

Table 2: Card Ranking Exercise

Word/phrase	Derivation (AM= Agile Manifesto)
Collaborative	AM Principle N4: "*Business people and developers must work together…*"
Contributed to science	Project goals
Cross-disciplinary	Project goals
Experimental	Project goals
Fast-paced	AM Principle N8: *"...maintain a constant pace indefinitely"*
Open to change	AM Principle N2: *"Welcome changing requirements…"*
Produced prototypes rapidly	AM Principle N3: *"Deliver working software frequently…"*
Reflective	AM Principle N12: *"At regular intervals, the team reflects…"*
Self-directed	AM Principle N5: *"... and trust them to get the job done"*
Valuable for communities	Project goals
Valuable for partners	Project goals
Valued people over process	AM Value N1: *"Individuals and interactions over processes and tools"*

The second exercise asked participants to rank a set of cards, each with a different word or phrase, onto a grid (Table II and fig. 3). As a set, these cards expressed possible features and characteristics of the flood sprint. The cards were devised through collaboration between two of the authors. Their derivation was based on two main sources: the Agile Manifesto [23], and the project goals, as expressed in early project documentation. It should be noted that the Agile Manifesto – a set of 12 principles and four underlying values widely used and referred to within the software development community – was not a point of reference for the flood sprint. Rather, this manifesto was used by the re-searcher as a source of potentially resonant vocabulary, which could allow for various emergent views about the characteristics of the flood sprint to be explored. This allowed for the exploration of features of the flood sprint that might not have been laid out as goals or 'hoped-for' attributes of the approach from the outset. Table II outlines the cards and the derivation of the words/phrases.

These cards were introduced to interview participants as representing envisaged advantages of the agile approach, and they were asked to rank them on the grid (see fig. 3) according to how present they were during the flood sprint (a five-point Likert scale ranging from 'never' to 'always'). Participants were then asked whether, though often claimed as beneficial, any of these features had a more negative or neutral side. An opportunity was also given for participants to add anything they felt was missing from the existing selection of characteristics onto blank cards. The ranking exercise was not designed to gather quantitative survey-style data but rather to elicit qualitative responses to the words/phrases and to provide insight into participants' perceptions of the characteristics of the process.

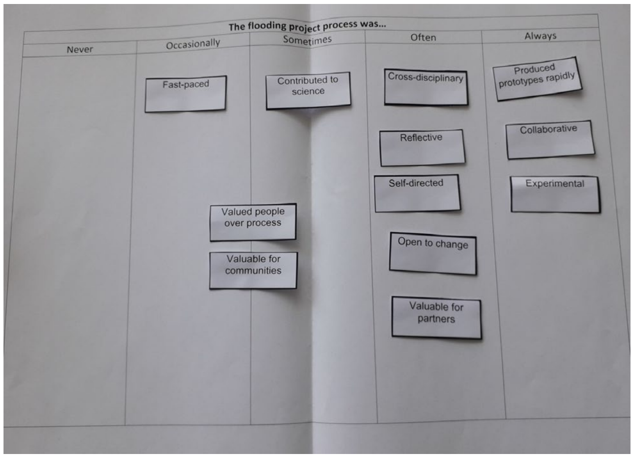

Figure 3: One participant's completed card exercise

5.3 Ethical Considerations

The study had full ethical approval from the University's Faculty of Science and Technology's ethics committee. Special consideration was given to the sensitivities around interviewing the research team, some of whom are still employed on the same research programme. Some of the research team had a few concerns and reservations about taking part in this research. Several measures were put into place to allay these concerns.

Firstly, given the participants' potential identifiability and the research need for participants to be referred to by role in publications, participants were made fully aware of this and the consent form specifically asked for permission to refer to participants by role. Care has been taken to keep role descriptors minimal and for identifying features (such as organisation or academic discipline) to be removed in quotations. Secondly, and in response to the issue of identifiability, all participants were given the opportunity to view their transcript and request for certain sections not to be quoted in any publications, if so desired. Half of the participants took up the opportunity to review their transcript, though there were few requests for either the removal of sections or the rephrasing of expressed ideas. Thirdly, any discussion that took place before or after the recorder had been switched on or off respectively was taken as firmly off the record. Finally, the decision was made that the full transcripts would only be seen by the interviewer, not by the other authors, one of them being the project PI and manager of these researchers. This decision was made following discussions that occurred after the first few interviews, but before any interviews were transcribed. This decision was then communicated to all participants. This is an important example of reflexive research ethics, ethics not just being a tick-box exercise prior to the research being carried out but instead something that may require careful negotiation throughout the research process. In this case, an additional mechanism not originally considered was required for the reassurance of research participants.

5.4 Interview analysis

Interviews were fully transcribed and thematically coded by the researcher, using NVivo to assist the process. In order to consider the reliability of the codes, the researcher selected a sample of 20 quotes and their associated codes. These were sent to the other authors in two separate files – one of quotes and one of codes. The other authors were asked to assign the relevant code(s) to each quote. Alignment with the original coding was achieved in the vast majority of cases (~90%) and any differences of interpretation were discussed between all three authors.

6 Evaluative Reflection on Realisation of Principles

This paper will now consider firstly, the extent to which the core principles were realised, and secondly, the effectiveness of their key supporting mechanisms (e.g. tools, techniques). By its nature, this is an arbitrary distinction, the relationship between principles and their supporting mechanisms being far more entangled, with organic intersections between the two aspects. However, the section on principles will predominantly consider more abstract viewpoints and perspectives about general qualities of the flood sprint. The evaluation of the effectiveness of the mechanisms will be more concerned with concrete specifics. Having discussed both these things, the paper will conclude by returning to the intuitions initially proposed. Throughout these three sections, key lessons learnt are highlighted.

6.1 Collaborative Partnership

The collaboration achieved between the core team and the external partners was one of the most positive elements of the flood sprint identified by the interviewees. The core team emphasised the "constant communication, constant collaboration" (R1) and "good rapport with external" (R3). R1 commented that it felt like "a partnership rather than just a one-way relationship", while PrA observed that partners came to feel "like they genuinely were part of the project […] that they were part of the team". This was echoed by the partners. EP1, for example, highlighted that it did not feel like "contractor-client or something of that nature" but rather that "we were all working together as one entity […] we were all integrated". EP2 echoed this, stating that "we were definitely considered part of the project team and there was a lot more active involvement".

This didn't mean just working closely together but also that external partners were central in shaping the work and what was delivered. Observing the process, steering committee member SC1 highlighted the flood sprint as one of "co-development of the knowledge and a co-development of the solutions". Stakeholders played an important role in setting the research agenda. R3 explained, "it's only when we met [partner] and we chatted with [them] and [they] explained what the challenges are that they face in the flood domain that we came up with the idea of working on the integration of data". EP2 commented on how the core team "frequently sought feedback" and that "they did respond and reflect our thoughts and adjust and were able to deal with some of the data challenges".

The core team ended up working closely with a small range of external partners within a wider group of stakeholders. The PI identified the emergence of "super participants […] people who are really pivotal and became very important to us", while PrA similarly highlighted partners who were "really integral to the success of the flood sprint". This was echoed by R1, who commented "I don't think we'd have got anywhere near as far as we did without [partner's] involvement". A key lesson learnt here is the value in identifying external partner champions and prioritising a small number of in-depth relationships rather than a broader, but shallower network.

6.2 Reflectiveness

There were mixed opinions as to how reflective the flood sprint was. The PI felt that the core team were "highly reflective" and R2 agreed that "it was a very reflective process […] there was lots of conversation about how we were doing things, what we were doing, how it was doing". By contrast, PrA didn't experience much of "us doing it [reflection] as a team. Or in team meetings", and EP2 wondered "whether at times it was so fast-paced that perhaps there wasn't the time to reflect". This latter comment indicates that some principles may not necessarily complement each other and may in fact be contradictory. The "deep-dive" of the sprint necessitated a fast-paced working environment to ensure delivery by the end of the year, but this may have allowed less space for reflection.

One piece of evidence for reflectiveness is that some supporting mechanisms were changed because they weren't working. For example, the research team discontinued a reading group that, whilst being helpful at the start of the year, had ceased to serve a purpose. Early on, these reading groups had helped the researchers to gain "understanding of the domain" (R3) and "see how people approach different ideas" (R1), but later they "died out […] because of other demands" (R1). R4 explained that they were "no longer as useful" as the sprint progressed and as each researcher began to look "at different parts of the problem". This is also indicative of the third and fourth interlinked principles – iteration and openness to change.

6.3 Iteration and Openness to Change

For several interview participants, iteration and openness to change were seen as defining features of the agile approach taken by the flood sprint. R1, for example, spoke frequently of "iterating" or "the iterative nature" of the project. PrA defined the agile approach as "constantly evolving", and described a "cyclical process of do something, review, make changes, do something, review, make changes". SC2 defined it similarly: "it's adaptable, it's changeable, it's flexible. You change as you go along". R2 also commented on the "responsiveness" of the approach: "agile for me […] was not having a predetermined research programme – it was responding to people's concerns and issues". Such perspectives were echoed by external partners. EP1, for example, highlighted the "willingness to change". The openness principle was also supported through specific mechanisms. For example, the workshop facilitator embraced an approach that was "fleet of foot" with a selection of activities that emphasised change over a rigid structure (O1).

7 Evaluative Reflection on Supporting Mechanisms

7.1 Communication and Sharing Mechanisms

Several mechanisms were put in place to enable communication and knowledge sharing both between the core team and the partners and within the core team. For example, the sprint was kick-started by a launch workshop that brought together the core team and an invited group of flooding experts (N=25). This workshop was used to generate ideas that would go on to shape the flood sprint. Prototypes were then demonstrated at a closing workshop at the end of the year. The Manchester Science Festival also served as a key touchstone for the team, who exhibited a series of installations and physical and digital artefacts. In addition to these milestone events, there were regular mechanisms to support day-to-day research activities. For instance, the research team came together for reading groups in the first part of the year, as well as regular meetings with another research group. Contact with external partners was maintained formally through monthly show and tells over video-conferencing software, and informally through impromptu face-to-face meetings.

Workshops- There was a lot of positivity about the workshops. EP3, for example, described them as "truly fantastic" events that "showed a real new way of working". The key outcome from the first workshop was a series of four co-created storyboards. These were designed to "ascertain essentially what the flood risk industry wanted or needed and how we could facilitate that and help that" (R1). The four storyboards focused around models of everywhere, risk, computational infrastructure, and public engagement. Each researcher volunteered to champion one of the four storyboards: "the idea here was rather than us come up with a programme, we want you [the partners] to facilitate the discussions and the ideas and see what ideas […] would actually get traction in the broader user base" (R2). From partners, there was most interest in risk and public engagement, and a focus on these two areas was central over the course of the flood sprint.

Internal Communications- There was a strong sense that internal research team communications and sharing did not work very well, though different perspectives as to why this might be. A couple of respondents, for example, commented on the existence of mechanisms that undermined flexibility. R2, for example, was concerned that "we were wedded to some meetings

[…] and even now we have a bit of process issue going on that we could frankly do without". The PI agreed on the importance of "not trying to impose too much structure on what's a highly flexible, iterative process … sometimes the structure […] gets in the way".

However, in general, there was an expressed need for more structure. PrA stated that "from an admin point of view, I couldn't quite figure out how I was going to help the team monitor or keep track or plan the project", and identified a need for "project management […] it probably wouldn't just happen organically, or not as effectively". There were also specific instances where more structured mechanisms were desired. R3, for example, expressed the need for clearer, more transparent documentation within the research team: "many people are doing different things and then […] because of the agile nature they are moving to something else, but then you don't know what happened in the process". R3 explained further, "agile process has its benefits, 'cause if something's not working you can move to something else, but then you also need to report why it is not working". Core team meetings were held throughout the year but were focused more on "day to day housekeeping-y kind of things, not so much about our research" (R4). Finding the right mechanisms by which to regularly share research progress and work was challenging, and more informal agile-inspired tools (such as whiteboards) did not particularly gain momentum.

Show & Tells- The show and tells were a key formal mechanism for communicating with external partners and were conducted over video conferencing software. Most interviewees agreed that the show and tells were not effective. This lack of effectiveness was attributed to several things. Firstly, the team used the free version of the software that had a 40-minute time limit. As a result, the show and tells felt "really rushed" and attempts to "cover too many things" led to "superficial" feedback (PrA). R3 commented, "once you start to warm up to the discussion, then it would just abruptly stop when people wanted to ask questions, so that was a bit funny". As well as the time limit, there was a strong sense that the medium was not right. For R2, the video conferencing established external partners as "very passive, so they sit at a meeting, they dial in, and they want to listen to what you have to say or listen to what you've done". This was in contrast to a more open two-way discussion about "what are the priorities? What actually should the research programme be?", which was "quite difficult to do over a video system". R2 summarized: "for me the fundamental problem was it felt a bit like presenting our work for critique and feedback rather than 'we're all in this together guys, you know, this is our research programme, not, you know, doing a research programme for you'". R2 felt that the video conferencing allowed people to too easily "fall into roles". R4 agreed, stating "it felt like us presenting. It didn't feel like a two-way thing". One solution was getting researchers and partners to present work together. Another drawback was that the video conferencing software was not "as interactive as you would ideally want" (EP1), and R4 agreed that "you couldn't engage in the development of the prototypes using that format".

By contrast, informal, face-to-face collaboration with partners worked extremely well. Key external partners often dropped in on the research team, something that especially enabled collective prototyping. R2 highlighted the use of "technologies that are supportive of iterative and explorative programming so we could quickly do things on the fly […] you could quickly write in new code and you could see the outputs as well", leading to quick feedback from partners. R4 echoed this, stating that it was possible to see the software "incrementally improving because of [the partners'] input, so they were saying 'oh could you try this? Could you try that?". Through these informal face-to-face interactions, the researchers and partners also worked together using visualizations. R4 explained "there were lots of people drawing up their vision on a board and then other people editing it and challenging and questioning it and making adjustments to it, so it felt like a shared vision was being created".

The varying effectiveness of different sharing and communication mechanisms adopted in the flood sprint highlight the tension between structure and flexibility, something that has been acknowledged as a tension within agile [24]. Agile management hopes to "afford a balance between structural orderliness that ensures the project as a whole is achievable and a capacity for improvisation that enables responsiveness to new and changing user requirements" [19].

A key lesson learnt in the flood sprint was that, whilst internal collaboration may require more formal mechanisms, collaboration with external partners worked best at its more informal.

7.2 Sprint Cycle

The term sprint was used by Speedplay to refer not to different software iterations, as is the case in agile software development, but "the kind of focus or the domain that we were in" (O2). This was also how the sprint idea was employed for this project. The sprint did not work through short (e.g. fortnightly) iteration cycles and did not feature classic agile processes for the monitoring of these iterations, such as stand-ups or retrospectives. R2 explained that it wasn't like "agile processes as a software development programmer would think of agile. They often have daily meetings and scrum masters and all kind of things. It was never like that. It was agile as a philosophy really". The sprint – an intense, deep-dive into a particular research domain with the knowledge that this domain would change in the near future – had both advantages and disadvantages.

Advantages of the sprint- The sprint, in which a group of researchers with little or no background in flooding or flood risk management (with the exception of one researcher who had previously researched extremes and flood events) were tasked with developing digital technologies to advance flood risk management over the course of a year, was seen by participants to have several advantages.

Firstly, the year-long sprint was seen as timely and more closely aligned with practitioner timescales. A Steering Committee member commented on the sprint's "ability to engage the stakeholders on a focused activity where they could see within a realistic framework" and that partners could "see that the timing is at least a little bit closer to the timing when knowledge is needed and action is needed" (SC1). This perceived attitude of external partners was confirmed, as one explained: "sometimes with academic research it can feel like it takes a long time […] before it's actually delivered on the ground as it were and you see it making that actual difference, whereas in Ensemble it all happened in a very short space of time and, yeah, it was just great seeing that" (EP2).

Secondly, the sprint was seen to provide important focus. SC1 highlighted how "the sprint allows that focus and that emphasis on a particular area", whilst O1 commented on how the time constraints of a year could be useful in that "they sharpen the mind […] focus the mind".

Thirdly, the sprint should be seen in the context of a five-year long research framework, in which the structure of year-long sprints each tackling a different environmental challenge was designed to enable the asking of "some overarching questions around how you deal with uncertainty and how you deal with complexity […] but across different areas of the environment" (PI). R4 highlighted similarly how the past two and a half years had been partly spent "trying to see the connections between the themes" and identify "the overarching issues that cut across between floods and soils [year 2] and biodiversity [year 3]", whilst SC1 identified "cross-sprint fertilization and influence".

As well as the identification of threads across environmental challenges, the sprint cycle was seen to enable a process of "taking stock", allowing later sprints to build upon lessons learnt in relation to the approach taken. This was articulated by EP2, who stated: "Some of the good things about the flood sprint and what we've learnt and some of those early ways of working, and finding out what did work and didn't work and what could be better has kind of put [the] next sprint in a stronger position". This was echoed by SC1, who remarked that "I could see how they'd built on what happened in the flood sprint and were seeing what was happening in the biodiversity sprint".

Disadvantages of the sprint- The key challenge of the flood sprint was its year-long timeframe and its subsequent time constraints and pressures. This was particularly felt by the research team, who identified a strong sense of pressure to deliver something by the sprint's closing workshop. R3 commented on the "pressure of delivering", which was "very, very stressful", while R4 stated that they felt "under pressure at the end and exhausted at the end". It was also challenging for external partners, as EP2 explained: "From our side, knowing that actually this was really time limited and we needed to kind of prioritize this … much higher than some of our other academic projects, because actually it was going to go ahead and proceed anyway, whether they had our feedback or not or whether we could provide data and so setting those expectations early on. I guess I hadn't quite appreciated some of that".

Another dimension of the year-long sprint timeframe was the sense that the sprint ended just as progress was really starting to be made. This was expressed again by EP2: "for me it felt like it was working really well in months four to six, and it felt like we were making great progress and then it came to an end *laughs* I found it was quite 'ooh…if only we had those first three months again' sort of thing and it was a bit longer, we could have achieved so much more". O3 also emphasized this, stating "you seem to be getting into something and then it was close to the end". SC2 shared similar concerns about whether a year was long enough, particularly given the "long process of trying to understand the state of the art".

The switch between sprints was felt particularly strongly by the researchers. R1 explained that "we generated some great ideas and generated some real interest but then we had to stop and work on something else". In addition, the research team would "get familiar with something and then you're finishing it".

Most of these concerns about the timeframe were pragmatic, but R4 expressed a more philosophical concern, based upon a belief in the "value of longevity […] and what you get from longer engagements that maybe you don't get short-term, because people are maybe less honest with you at the start of a relationship or you need to properly understand the context and you don't necessarily get that with short-term things".

7.3 Prototyping

The flood sprint produced many outputs. Key digital prototypes investigated appropriate software architectures and tools to support a more data-centric approach to flood risk management. This included using semantics and triple stores to store, integrate and query complex environmental data; the use of such techniques to identify the veracity of data and to highlight missing data and inconsistencies; and the use of Jupyter Notebooks to support collaboration and to combine quantitative and qualitative material, and data visualisations. This overall flood sprint conceptual design is shown in fig. 4.

These prototypes were developed with the aid of techniques familiar to agile software development, for example, user stories, as R2 explained: "The idea there was to write a narrative from a particular user's perspective – flood risk manager, or data scientist […] and we wrote those out to focus us on what we needed to deliver and we did that in collaboration with this small number of participants that we had all the way through […] and then we used those user stories to drive the programme that we developed, the software that we developed".

The Manchester Science Festival also brought together a series of digital and physical artefacts. These included an interactive flood preparedness kit, a magnetic flood-resistant kitchen, and ShapeClips used to visualise flooding. All of these exhibits aimed to engage the public around flooding, improving their awareness and preparedness.

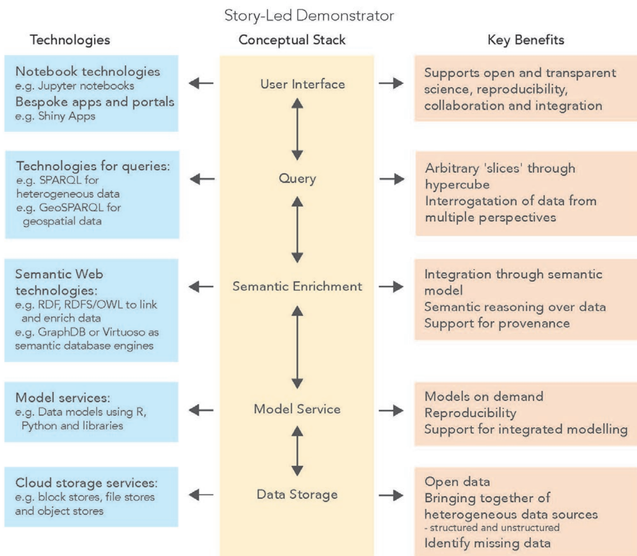

Figure 4: Flood sprint overall conceptual design

Although, as stated above, collaborative prototyping enabled successful engagement with external partners, there were also disadvantages connected to prototyping. One key disadvantage was related to ensuring longer-term legacy. One external partner expressed the view that the focus on "we're going to build a little bit and knock it about a bit and then rebuild it slightly differently" could distract from prioritizing legacy, and giving enough thought to "actually at the end of this, I'm going to have this really important thing. And I need to think early on about how I'm going to deal with that, how I'm going to manage it" (EP1). Similarly, SC2, despite seeing rapid prototyping as "brilliant", was unsure whether it was able to "produce […] something that is used". In the case of some of the software prototypes produced, the data used was not open access, creating a further barrier to usability.

The challenge of developing prototypes into a software product or service that could be widely used was particularly expressed by EP2. EP2 highlighted that "being able to extract stuff out of static documents that then you could link in inter-active spatial visual displays is fabulous". However, "it's not quite gone far enough to be in a state for us to pick it back up and then use". EP2 explained further: "It's not […] demonstrated beyond that small data set that this could work at a national scale or if you had huge volumes of data you needed to process in this data, how long would it take? […] but then they've unlocked what's a huge world out there for us but then it's how do we take what they've unlocked and proved possible to get it to a stage where we could apply it and use it". The challenge was to "translate that proof of concept into something that's a much bigger, automated way of doing things". Expectations were also high due to being so involved in the project: "because we felt we'd been so more integral to it and we helped shape and steer it so much that then it was like well then how do we make this tangible? Because we want this now" (EP2).

These views of the disadvantages of prototyping were not fully echoed by the research team. R2, for example, stressed that the prototypes' role was to be a "medium […] to provoke and motivate and generate ideas" and commented that "it's not often like that in a software development world. In a company that would be different, but this is about research. It's different". R2 also highlighted how "it's not really a piece of software that would go to a company and be used. It's a medium to demonstrate ideas around flexibility and exploratory programming". This raises questions around how to manage the different expectations of external bodies and academia.

There were also strategies to plan for longevity and sustainability and these did have some success. For example, parts of the project were taken forward with a Knowledge Transfer Partnership, a UK-wide programme that brings together businesses with relevant science and technology research.

8 Returning to the Intuitions

The intuitions of this research were that adopting a set of agile principles and supporting mechanisms would 1) enable effective transdisciplinary work; 2) embed stakeholders into the research process; and 3) facilitate the design, development and implementation of digital prototypes. It is clear from the above analysis that this approach embedded stakeholders into a meaningful research collaboration in which they were an integral part (2). Whilst the prototypes created did raise some issues around legacy, the flood sprint created a wide array of prototypes that were well received by partners and stakeholders (3).

When it comes to (1), the picture is more complex. The flood sprint enabled work across disciplines and with a range of stakeholders. However, it seems to have been more successful in bringing researchers together with partners than bringing researchers together in a meaningful transdisciplinary way. The project as a whole was transdisciplinary, but the work produced by individual researchers was largely not, as there was less collaboration between the core members of the research team. R2 explained, "'I think there was an overarching philosophy here that we were working as a team [...] and that probably was too much of an ask I think given the different approaches to work, the different backgrounds, intellectual backgrounds, different disciplines that we've all come from'. R3 agreed that working as a team was "very difficult [...] very challenging".

Part of this challenge came from the perspective of career development: "because [...] we're coming from different backgrounds, there is a thing to do with your career and the project [...] for some people it matters a lot where they publish in terms of getting their next job" (R4). Current academic structures and norms – especially the expectation of having a niche – do not necessarily make it easy for early career researchers working in more transdisciplinary spaces. For example, it has been noted that "academic progression and promotion favours a mono-disciplinary approach, whereas career pathways for transdisciplinary researchers are less straightforward" [1].

9 Conclusion

This paper has highlighted the agile principles and supporting mechanisms used to support transdisciplinary research into a "wicked" environmental problem. The success of this approach in drawing stakeholders into a collaborative research programme, including co-creation of working prototypes, suggests that agile methods have an important role to play in approaching such research. Further work is needed to consider ways of enabling transdisciplinarity internally within a research team and to consider the translation of prototypes into long-lasting valuable artefacts.

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REFERENCES

[1] Frances Harris and Fergus Lyon, 2014. *Trandisciplinary environmental research: a review of approaches to knowledge co-production.* The Nexus Network. Available at https://thenexusnetwork.org/wp-content/uploads/2014/08/Harris-and-Lyon_pg.pdf

[2] Katherine Mattor et al. 2014. Transdisciplinary research on environmental governance: A view from the inside. *Environmental Science and Policy*, vol. 42: 90-100.

[3] Peter J. Balint, Ronald E. Stewart, Anand Desai, Lawrence C. Walters, 2011. *Wicked Environmental Problems: Managing Uncertainty and Conflict,* Springer.

[4] Maria Angela Ferrario, Will Simm, and Jon Whittle. 2013. Speedplay, managing the other edge of innovation. *Open Digital: Digital Futures Conference*, 1-3.

[5] Maria Angela Ferrario, Will Simm, Peter Newman, Stephen Forshaw, and Jon Whittle. 2014. Software engineering for 'social good': integrating action research, participatory design, and agile development. In *Companion Proceedings of the 36th International Conference on Software Engineering* (ICSE Companion 2014). ACM, New York, NY, USA, 520-523.

[6] Jon Whittle, Maria Angela Ferrario and Will Simm. 2020. Community-university research: a warts and all account. In Alan Chamberlain and Andy Crabtree, eds. *Into the Wild: Beyond the Design Research Lab*. Springer International Publishing.

[7] Centre for Research on the Epidemiology of Disasters and the United Nations Office for Disaster Risk Reduction. 2015. *On the Human Cost of Weather Related Disasters – 1995-2015.* Technical Report: CRED, UNISDR, 10.13140/RG.2.2.17677.33769.

[8] European Environment Agency. 2016. *Floodplain Management: Reducing Flood Risks and Restoring Healthy Ecosystems.* Available at: https://www.eea.europa.eu/highlights/floodplain-management-reducing-flood-risks.

[9] Paul Sayers et al. 2013. *Flood Risk Management: A Strategic Approach*. UNESCO.

[10] HM Government, 2016. *National Flood Resilience Review*. https://www.gov.uk/government/publications/national-flood-resilience-review

[11] Steve Easterbrook, 2014. From computational thinking to systems thinking: a conceptual toolkit for sustainability computing. *ICT for Sustainability 2014* (ICT4S-14). Atlantis Press.

[12] Horst W. J. Rittel, and Melvin M. Webber. 1973. Dilemmas in a general theory of planning. *Policy Sciences*, vol. 4, no. 2: 155-169.

[13] Julia Leventon, et al. 2016. An applied methodology for stakeholder identification in transdisciplinary research. *Sustainability Science* vol. 11, no. 5: 763-775.

[14] Daniel J. Lang, et al. 2012. Transdisciplinary research in sustainability science: practice, principles, and challenges. *Sustainability Science*, vol. 7: 25-43.

[15] Craig Larman. 2003. *Agile and Iterative Development: A Manager's Guide*. Pearson Education.

[16] Helen Sharp, Laura Plonka, Katie Taylor, and Peggy Gregory, 2014. Overcoming challenges in collaboration between research and practice: the agile research network. In *Proceedings of the 1st International Workshop on Software Engineering Research and Industrial Practices* (SER&IPs 2014). ACM: 10-13.

[17] Janna Järvinen, Tua Huomo, and Tommi Mikkonen, 2017. Running software research programs: an agile approach. In *Proceedings of the 39th International Conference on Software Engineering Companion* (ICSE-C '17). IEEE Press, Piscataway, NJ, USA: 314-316.

[18] Andrew Mara, Liza Potts, and Gerianne Bartocci. 2013. The ethics of agile ethnography. In *Proceedings of the 31st ACM International Conference on Design of Communication* (SIGDOC '13). ACM, New York, NY, USA: 101-106.

[19] Enric Hidalgo. 2018. Management of a multidisciplinary research project: A case study on adopting agile methods. *Journal of Research Practice*, vol. 14, no. 1: 1-17.

[20] Anna Börjesson Sandberg and Ivica. Crnkovic. 2017. Meeting industry: academia research collaboration challenges with agile methodologies. *In Proceedings of the 39th International Conference on Software Engineering: Software Engineering in Practice Track* (ICSE-SEIP '17). IEEE Press, Piscataway, NJ, USA: 73-82.

[21] Maria Angela Ferrario, Stephen Forshaw, Peter Newman, Will Simm, Adrian Friday, and Alan Dix. 2014. On the edge of supply: designing renewable energy supply into everyday life. *ICT for Sustainability 2014* (ICT4S-14). Atlantis Press.

[22] Kenneth S. Rubin. 2012. *Essential Scrum: A Practical Guide to the Most Popular Agile Process (1st. ed.).* Addison-Wesley Professional.

[23] Kent Beck et al. 2001. *Manifesto for Agile Software Development*. Available at https://agilemanifesto.org/

[24] Helena Tendedez., Maria Angela Ferrario, and Jon Whittle, 2018. Software Development and CSCW: Standardization and Flexibility in Large-Scale Agile Development. *Proceedings of the ACM on Human-Computer Interaction*, (CSCW) 2: 1-23