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Coproducing flood risk knowledge: redistributing expertise in critical 'participatory modelling'

Catharina Landström
School of Environmental Sciences, University of East Anglia, Norwich NR4 7TJ, England; e-mail: c.landstrom@uea.ac.uk
Sarah J Whatmore
School of Geography and the Environment, University of Oxford, South Parks Road, Oxford OX1 3QY, England; e-mail: sarah.whatmore@ouce.ox.ac.uk
Stuart N Lane
Institut de Géographie, Faculté des Géosciences et de l'Environnement, Université de Lausanne, Lausanne CH 1015, Switzerland; e-mail: stuart.lane@unil.ch
Nicholas A Odoni
School of Geographical Sciences, University of Bristol, University Road, Bristol BS8 1SS, England; e-mail: nick.odoni@bristol.ac.uk
Neil Ward
Faculty of Social Sciences, University of East Anglia, Norwich NR4 7TJ, England; e-mail: n.ward@uea.ac.uk
Susan Bradley
Centre for Rural Economy, School of Agriculture, Food and Rural Development, Newcastle University, Newcastle upon Tyne NE1 7RU, England; e-mail: susan.bradley@ncl.ac.uk
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Abstract. This paper suggests that computer simulation modelling can offer opportunities for redistributing expertise between science and affected publics in relation to environmental problems. However, in order for scientific modelling to contribute to the coproduction of new knowledge claims about environmental processes, scientists need to reposition themselves with respect to their modelling practices. In the paper we examine a process in which two hydrological modellers became part of an extended research collective generating new knowledge about flooding in a small rural town in the UK. This process emerged in a project trialling a novel participatory research apparatus—competency groups—aiming to harness the energy generated in public controversy and enable other than scientific expertise to contribute to environmental knowledge. Analysing the process repositioning the scientists in terms of a dynamic of 'dissociation' and 'attachment', we map the ways in which prevailing alignments of expertise were unravelled and new connections assembled, in relation to the matter of concern. We show how the redistribution of knowledge and skills in the extended research collective resulted in a new computer model, embodying the coproduced flood risk knowledge.

Introduction

As public controversy over science-based environmental decision making has become a growing concern for the authorities responsible, public participation has been introduced as a measure to create more trust and prevent conflict (Irwin, 2009). This 'rationalist' driver (Owens, 2000) for public engagement, based on an assumed need to educate and persuade the public in order to produce social agreement on science-based strategies and options, finds support among actors responsible for environmental policy making and management (Holliman and Jensen, 2009). However, the success of such measures can be questioned. For example, Wynne (2006) notes "the intrinsic futility of trying instrumentally to engender public trust in science, whether by 'public engagement', dialogue, or any other means" when the "objective is to manage and control the other's response" (pages 219–220). In contrast, a 'civic' rationale (Owens, 2000) for public engagement aims for more democratic participation, encouraging wider questioning of the assumptions underpinning decision making. This approach opens up for discussing the topics of what public participation is trying to achieve and how to effect it (Stirling, 2008; Whatmore, 2009). In this discussion attempts are being made to understand public controversies differently, not as failure of governance, but as opportunities for engaging publics in new lines of research, which address their matters of concern. Callon et al (2009) suggest using the generative force of controversies to enrich democracy, to bring new actors into deliberation, and to prompt new exploration by challenging established knowledge. Successfully using controversy in this way amounts to a redistribution of expertise in relation to a specific social context in which the authority bestowed on science-based knowledge is not a priori granted priority over experience-based knowledge with regard to a local problem.

This paper examines the redistribution of expertise occurring within the framework of an experiment with public engagement—competency groups (CGs)—that uses public environmental knowledge controversies as a generative force. Experimental in the sense of being open-ended, CGs aim to 'coproduce' knowledge through bringing scientists and concerned publics together. This amounts to redistributing expertise in the sense of repositioning knowledge claims based in different practices in relation to each other. This entails an understanding of expertise as reproduced in local contexts rather than a property of certain actors. Redistributing expertise based on scientific knowledge requires that scientists engage with lay people in new ways because "accustomed to living in their entrenched fields, researchers end up with eyes only for the problems which are born in their laboratories" (Callon et al, 2009, pages 94–95). For new knowledge claims to be generated by the force of controversy, science needs to become part of "extended research collective[s] including emergent concerned groups" (page 125). This raises the question addressed in this paper: how can scientists be brought into effective collaborations with lay publics?

This paper analyses how collaborating with local residents in a CG changed the way in which the participating scientists worked. The process is conceptualised as a dynamic of 'dissociations' and 'attachments', referring to the active distancing from previously dominant defining connections and the forming of new relationships that become constitutive of agency in relation to the matter of concern. Dissociations and attachments are understood to be sequential acts producing situated cultural meanings in the processes that, over time, define actors and distribute agency. Every scientific research project requires dissociation from previous knowledge in order to progress, but in order to get a new direction the research needs new attachments (Callon et al, 2009, pages 262–265). In this case the CG provided attachments not normally available to university scientists.

In the following we map the dynamics of dissociation and attachment which reorientated the work of the two natural scientists; hydrological modellers, experts in numerical modelling, and members of an interdisciplinary project team trialling CGs as a new methodology for public engagement.(1) We examine how the attachment of the scientists' knowledge and skills to the matter of concern resulted in the coproduction of knowledge in an extended research collective. We illuminate the embodiment of the new knowledge in a new computer model, which transported the propositions

(1) "Understanding environmental knowledge controversies: The case of flood risk management" (http://knowledgecontroversies.ouce.ox.ac.uk), a project interrogating the knowledge controversies associated with flood risk in the UK, was funded under the UK Research Councils' Rural Economy and Land Use (RELU) Programme 2007–10 (ESRC Award RES-227-25-0018).

articulated by the collective to other actors and arenas. The paper uses material generated from three different angles: first, an ethnographic study of the scientists' work by the team members specialising in social studies of science; second, accounts of the modelling by the scientists in the context of the project; and, third, reflections by the project team members who worked with the staging of the local collaboration. We also draw on video and audio recordings from CG meetings. Coauthoring brings the different materials and experiences together in a joint narrative, beginning with an explanation of the CG experiment. Thereafter we describe the process of dissociations and attachments that shaped the modelling process and the computer model resulting from it. Finally, we reflect on what the competency group modelling experience implies when scientists collaborate with lay people.

Extending research collectives through computer modelling

The CGs were staged in the midst of public controversy over institutional flood risk management, underpinned by computer simulation modelling. The character of the science being contested in the localities led to a focus on modelling in the groups which aligns them with participatory approaches at the intersection of software development and environmental management. In participatory modelling (PM), computer programs facilitate collaborations of scientists and lay publics in environmental management, as a means of incorporating knowledge from "various stakeholders, sources, and research disciplines" (van Kouwen et al, 2009, page 63). A practice within this field, companion modelling (ComMod), focuses on local communities, aiming to "facilitate dialogue between the different stakeholder concerned by a given local issue of natural resource management" (Souchère et al, 2010, page 1360). PM and ComMod become relevant counterpoints in this analysis because the CG in focus evolved as an exercise in modelling flooding in a particular locality.

Explicitly aiming to redistribute expertise, CGs were based on a civic rationale for public engagement (cf Whatmore and Landström, 2011). This ethos distinguishes them from PM defined as "the use of modelling in support of a decision-making process that involves stakeholders" (Voinov and Bousquet, 2010, page 2). The rationalist logic of engaging the public in order to produce agreement and better solutions is strong in PM, and has been invoked in a number of river basin management studies (Cockerill et al, 2006; Johnson, 2009; Vari and Kisgyorgy, 1998). In contrast, CGs aim to 'coproduce' knowledge as defined in Callon's (1999) three-fold distinction between types of public engagement: (i) 'public education' (teaching the public about what scientists know); (ii) 'public debate' (facilitating the public's questioning of scientists); and (iii) 'coproduction' of knowledge which indicates a redistribution of expertise through the collective investigation of problems.(2) Coproduction of knowledge thus exceeds PM's aim of creating "a platform for integrating scientific knowledge with local knowledge and when executed well provide[s] an objective, value-neutral place for a diverse group of stakeholders to contribute information regarding water resource issues of interest" (Voinov and Gaddis, 2008, page 198).

The CG methodology requires participants to be willing to engage as individuals, with their own particular knowledge, skills, and expertise, rather than as representatives in the sense of spokespersons for preexisting bodies with political aims or established agendas (eg local councils, countryside lobby groups, or community associations) or as

(2) Callon's (1999) notion of 'coproduction' differs from Jasanoff's (2004) use of the term. Jasanoff and others, investigate the evolution of the social institutions of science, policy, and media—historical phenomena observable on the societal level—while Callon's point of reference is face-to-face interaction of scientists and publics.

in the sense of representing a category of people (eg farmers, women, or pensioners). This sets CGs apart from both PM and ComMod in which participants acts as representatives for institutional stakeholders or categories of local residents (cf Castella et al, 2005). The CG emphasis on participants not acting as representatives resembles the deliberative mapping (DM) approach. DM challenges expert identities as it draws "attention to the boundedness of different kinds of expertise and raises new uncertainties" (Davies, 2006, page 246) in a process that "allows all participants to scrutinize how problems and solutions are framed in different specialist knowledge communities" (page 246). The ambition of CGs to redistribute expertise requires that participants can change in the process, which is difficult if they are to represent others who are not taking part. This involves a conception of expertise as 'situational', in principle open to negotiation in new contexts, but in practice often established in institutional networks preceding the relationships established in the local context. This approach is specific to the CG experiment and it differs from the way in which expertise is usually conceptualised in science studies (cf Collins and Evans, 2007).

Unlike PM projects, CGs do not necessarily use models but, because computer simulation modelling plays a key role in UK flood risk management at the centre of the public knowledge controversy, it became critical to the project discussed here. The scientists participating in the CGs were experts in numerical modelling and the importance of modelling means that elements in the CG practices resemble the work undertaken in PM research. However, there are important differences that can be made clear by detailing a typical PM approach.

Videria et al (2009) describe a PM river basin planning project running over nine months in Baxio Guadiana, Portugal. The project is described as centring on three workshops in which stakeholder knowledge and views were articulated. Between the workshops the researchers undertook 'behind the scenes' tasks. It began with 'behind the scenes work' defining the modelling team, identifying and inviting stakeholders, and preparing the workshop. The first workshop involved fifty-seven stakeholder representatives in "defining the problem and conceptualizing the quantitative model" (page 970). More 'behind the scenes work' was to report preliminary results and describe a causal loop diagram developed in the workshop. The second workshop, with seventeen stakeholder representatives, conceptualised the simulation model, generating a "stock-and-flow model with a total of 91 variables distributed along 3 model sectors" (page 971). Afterwards 'behind the scenes work' involved data collection as well as "defining equations; quantification of parameters; check the model for logical values; conduct sensitivity analysis and validation tests" (page 969). Twenty stakeholder representatives attended the third workshop when the model was run with different policy scenarios and the outcomes discussed, recommendations developed, and objectives and actions arising from the participatory process drafted. After the workshop follow-up activities took place behind the scenes, such as distributing a questionnaire to participants and training some of them to use the model.

The PM process of work taking place in the extended research collective as well as in the research team is very similar to what unfolded in the CGs. However, the CGs were not intended to bring local participants' knowledge into the formal decision-making process, but to bring science out of the institutional networks normally managing flood risk. The participating scientists wanted to learn about local catchment processes by trying out hydrological and hydraulic modelling approaches not normally applied to local flooding, but had accepted that the methods that they would use would arise from discussion within the CGs and recognised the possibility of prioritising other approaches than modelling. In 'behind the scenes' work in CGs scientists not only prepare for collective activities, they also try to change their way of working.

The ambition of the scientists to change their ways of working sets CGs apart from PM, which does not question the role of science, beyond calling for "adaptation of the scientific modeling process to incorporate community knowledge, perspective and values" in order to avoid "potential conflict, misunderstanding and even litigation" (Voinov and Gaddis, 2008, page 198). CGs are also distinct from ComMod in which science provides tools for local learning, but does not change in the process (Castella et al, 2005; Souchère et al, 2010).

Framed by a critique of the established practices of science-based flood risk management CGs draw on science studies to question existing relationship between science and management which exclude other forms of knowledge and local publics. This framing was also present in a modelling project by Yearley et al (2003) that enabled local residents to articulate their experience-based knowledge as critical counterpoints to the scientific modelling of air pollution used by the local planning authorities. Critical of the limitations of UK statutory consultations done "through public meetings, through questionnaire surveys and other information distributed door-to-door and, of course, through consultations with councillors, the locally elected politicians" (page 250) Yearley et al set out to develop an approach that could "augment and provide an alternative to such consultative exercises, principally by broadening the kinds of input that citizens could have" (page 250). Working with model outputs in the form of maps involved no modelling, but demonstrated the ability of local residents to articulate experience-based knowledge in ways that could improve the overall understanding of the environmental problem.

Staging competency groups

The project team staged two CGs, each lasting around twelve months; one in Ryedale (North Yorkshire) and one in Uckfield (East Sussex). Each group centred on bimonthly meetings, supplemented by a variety of other activities that emerged in the course of the work, such as field visits, 'data' collection, and video recording. In each case, group membership comprised six to seven project team members and five to eight local members, plus a dedicated video recorder operator. In contrast to the PM project described above, CG membership remained relatively stable over time. There was also communication within the groups between meetings, via password-restricted websites, hosting resource depositories for materials collected by group members and group blogs for discussion.

The CGs required that both the natural scientists and the social scientists in the project team collaborate with the residents, rather than elicit 'local knowledge' and 'stakeholder values'. Based on a science studies conception of science, the CGs understood modelling as a scientific practice shaped in complex relationships, and hence changeable. Crucially the work in the groups was intended to impact on the relationships normally shaping flood risk modelling, not upon the decision making as in PM. To participate the scientists had to be willing to allow their practices to be shaped by a new network of relationships created through the CGs. It is the way in which the scientists came to dissociate from their normal network, to attach instead to the extended research collective emerging in the CG staged in Pickering, a market town in Ryedale, which this paper examines.

The first dissociation—a critique of standard flood modelling approaches

The first step of interest to the present analysis was dissociation, in the form of a critique of the standard way of estimating flood risk in the UK. Normally the determination of flood risk associated with rivers and the design of schemes to reduce that risk, proceeds through a two-stage process: the first hydrological and the second hydraulic.

The requirements of hydrological and hydraulic analyses are institutionalised through the notion that any flood defence project must be economically viable. That is to say: the benefits of the scheme must exceed the costs. Even though nonfinancial considerations are increasingly recognised as important, financial criteria have to be met (EA, 2010). A series of guidance notes issued by the Ministry of Agriculture, Fisheries and Food (MAFF)[3] in 2000–01 set out this framework called *Flood and Coastal Defence Project Appraisal Guidance*. The Environment Agency of England and Wales (EA) brought together and updated these notes in 2010 (EA, 2010). Their central premise is that the greatest net benefit nationally can be achieved through proactive application of a consistent cost–benefit analysis.

The aim of the cost–benefit analysis is to provide a baseline against which any kind of defence scheme can be tested. This treats floods events as stochastic in the sense that an event of a given magnitude has a probability of occurrence in any one year and that each event will also result in a certain set of economically quantifiable consequences. Risk is then defined as 'probability × consequences'. Hydrological modelling is used to determine the probability of events of different magnitudes, generating a set of river flows that can be applied to hydraulic models. The hydraulic models determine the spatial patterns of flood inundation associated with each flow for application in an analysis of consequent economic losses. When this analysis is complete, options appraisal begins, wherein the economic benefits of different options are tested using whichever hydrological or hydraulic model is most appropriate for that option.

The basic hydrological models, used in almost all flood risk assessments undertaken by the EA's expert consultants, are provided by the *Flood Estimation Handbook* (FEH) (CEH, 1999). There are two primary sets of methods associated with the FEH: (1) estimation of the probabilities of rainfalls of different depths and a means of transforming rainfall estimates into river flow estimates, updated in 2006 to the Revitalised Rainfall–Runoff Method (ReFH) (Defra, 2005); and (2) the statistical method, suited to locations with longer records of river flow, where the direct analysis of the river flow time series is used to estimate the probabilities of a range of different flows. The rainfall–runoff method can be traced to the Flood Studies Reports (FSR), published from 1971. The FEH brought all the reports together into a single framework and updated the data used to drive and to parameterise the models on the basis of the larger number of flood events that had been instrumented by the late 1990s.

The hydraulic treatments are commonly based upon transformation of the flows estimated using FEH into a time-dependent series of water levels for estimation of inundation extent. This practice has two elements: (1) representation of flow in the river channel, and its variation through time; and (2) determination of the spatial extent of inundation associated with that flow. Although the latter process is strictly two-dimensional, most analyses will use one-dimensional treatments that do (1) and (2) simultaneously, employing one of the two most widely used models in the UK at present, ISIS and HEC-RAS.[4] In the simplest of situations, the river cross-section is simply extended laterally to include the floodplain and the time-dependent flow applied to the extended sections. In more complex situations the floodplain may be divided into a series of connecting storage cells, with water allowed to flow between

[3] MAFF was replaced by Defra (Department of Environment, Food and Rural Affairs) in 2001 and formally dissolved in 2002.

[4] For information about these modelling software packages see: http://www.hec.usace.army.mil/software/hec-ras/ and http://www.halcrow.com/isis/default.asp

them according to water-level heights. In the most complex case the river channel flow is modelled in one dimension and used as a boundary condition for a two-dimensional treatment using a model such as TUFLOW.[5]

The project modellers considered the established two-step approach to be appropriate in many situations, but were critical of the way in which it restricts the kinds of solutions that might be explored, especially those where alternatives to traditional flood defence might be needed, such as upstream water management. In a working note produced for the project advisory panel in July 2007 they explained their aim to develop and to validate a 'minimal information requirement' model to investigate the effects of land management on flood risk. This was to be created by modifying an existing model to which they would add features allowing for simulation of spatially distributed rainfall and trace how this rainfall moves through the landscape.

At this point, the project modellers were undertaking a dissociation in which they were establishing the goals of their research as distinct from existing practice. This was not simply addressing a scientific debate over a particular method or idea, but a critique of an established approach to the application of science in management practice. Pickering was interesting to the scientists because of its geographical and contingent suitability: it had a large upstream, rural catchment, where traditional flood risk defence had been rejected on cost grounds, and the data needed for modelling could be made available by the local-area EA. Analysing previous flood modelling in Pickering, the scientists identified two important points. First was the critical question of determining the flows and how much excess water caused flooding. Second was the hydrological models treatment of all attributes upstream of the boundary (ie where they interface with the hydraulic model), as spatially integrated. Generally, the FSR – FEH – ReFH models have served flood risk management very effectively, but problems occur when they are used to assess flood risk reduction measures that are spatially explicit within the upstream river catchment. With these two issues in mind the project modellers decided to develop a physically based, distributed, hydrological model—CRUM2D v 3.1 (Lane et al, 2009)—as a means of exploring alternative ways of reducing Pickering's flood risk. By representing and analysing measures that increased infiltration into the land surface, they hoped to show that the resulting reduction in overland flow velocity could also reduce the size of peak river flows.

Constructing the research focus in this way positioned the project modellers in relation to both the scientific discourse and the local controversy. Dissociating from the science on which the EA usually bases its local interventions opened up the search for knowledge about the specific locality. This openness underpinned the scientists' interest in taking part in the public engagement experiment. They were convinced that it would enable the development of a model that would represent the impact of land-management measures on flood risk in Pickering better than EA consultants could. This dissociation from the usual way of modelling for local flood risk management contrasts with the PM approach, in which modelling is used to bring stakeholders and publics into the established networks of expertise and decision making (Voinov and Bosquet, 2010). The project team modellers were preparing to bring the science out of its usual relationships.

[5] See: http://www.tuflow.com/

The competency group in Ryedale

The project team began to recruit participants in Ryedale for the first CG in June 2007. Publicity in local newspapers, notices posted on community notice boards and shop windows, and leaflets distributed through library and museum networks invited people interested in flooding and its management to contact the researchers responsible for recruitment, who subsequently met respondents individually to outline the aims and working methods of the group (for details see Ryedale Flood Research Group, 2008). The active controversy in combination with a recent flood event seems to have prompted local interest in participating and the CG could start as planned.

The group met six times between September 2007 and July 2008 in Pickering, and the local participants were residents of the town or its surrounding area. Communications between meetings included letters, e-mails, telephone calls, and exchanges via a password-protected website, with a discussion forum (a blog). Between meetings, the researcher acting as coordinator/facilitator visited local members individually to gather feedback and suggestions for the following meeting's agenda.

While some of the social scientists established the CG, the modellers were considering what hydrological data they would need to represent flooding in Pickering with CRUM2D, where to get it, and how to run the model. They prepared printouts, pictures, and maps, representing different aspects of the locality: geology, hydrology, topography, land use, and rainfall. These were visual renderings of the data that would be used in the research to allow the model to represent the catchment as accurately as possible. As a step towards combining datasets in a way that would make it possible to initiate the CRUM2D model, they worked with data in the ArcGIS[(6)] program which allows the user to layer different types of maps on top of each other, thereby making it possible to see where different properties intersect (eg topography, rainfall, and soil type). They also resampled topographical data using a code they had written in another program to capture elevations in the catchment in a digital format that could be used in the model. Having undertaken this work, the modellers could come to the first meeting prepared with a modelling approach (CRUM2D) and scientific data about the river and the landscape.

This type of work is standard modelling procedure: in PM categorised as taking place 'behind the scenes'. In the context of the CG it was the initial step in making science part of an extended research collective, to which the scientists brought their prior experience of modelling this kind of environment, alongside the tools they had access to, data generated by scientific instruments, and the steer from working in a location where traditional flood defence had failed.

The first competency group meeting in Pickering

In this meeting the group began to construct a timeline for flooding in Pickering. Participants suggested a variety of sources, from records of the British Hydrological Society, to local histories, to talking with local people outside of the group. This activity quickly made it obvious that flooding was not a novelty in Pickering: it went back for centuries. Nor was it very rare: there appeared to have been periods of more frequent flooding, interspersed with stretches without floods. Next the project modellers introduced computer modelling of flooding to the group and we (all CG participants—local residents and natural and social scientists) talked about how it works and what it can be used for. In connection with this, the group began to identify what information would be needed in order to learn new things about flooding in Pickering (about flood events, the landscape, and features of the catchment).

(6) Developed and marketed by ESRI (http://www.esri.com) the ArcGIS suite of applications based on geographic information systems (GIS) is widely used across both the commercial and educational sectors.

An issue that arose in the first meeting was the connection of the project team to the EA. The independence of the project team from the institutions that had failed to address flood risk effectively in Pickering was crucial to the local participants in the CG. It was made clear that the source of funding for the project was the Rural Economy and Land Use (RELU) programme and that there was no formal connection to the EA.(7)

The EA had become part of the controversy in Pickering after it had commissioned several reports. Initial hydrological studies (referred to in EA, 2003) made use of the rainfall – runoff modelling strategy and focused on the large flood that hit the town in 1993. Floods also occurred in 1999 and 2000, and the EA submitted an application in 2001 for planning consent to construct a series of permanent flood defences (walls) along Pickering Beck in and near the town itself. This proposal was based on the two-step approach criticised by the project team modellers as too limited and there was consensus in the CG that the modelling work so far had been narrow and restricted.

That it was necessary for the project team to explicitly dissociate from the EA, in spite of not actually being formally connected to it, indicates the importance of public perceptions of the relationship between science and environmental management. In the local setting, flood science was perceived as connected with the EA and not trusted. A local activist (not participating in the CG) spoke vehemently of the EA:

> "Don't trust the Environment Agency. The Environment Agency—if they get their experts on it, they will pay them a fortune, and they will come up with a massive system. The Environment Agency cannot be trusted."

This distrust in the expertise and intentions of the EA and the science associated with it should not be regarded as an idiosyncratic local misconception because, as Wynne (2006) points out, "institutional science in many domains, from new technologies to public health, environment, and policy across the board, does indeed suffer from association in public experience with problematic and sometimes downright provocative institutional conditions, practices, assumptions, purposes and inconsistencies; and these are conducted in the name of science, normally with silent acquiescence, or positive support, from scientific institutions" (page 212). The project team had to explicitly dissociate from the EA in order to be accepted as working partners by the local residents. With the independence of the project firmly established and a second meeting scheduled, the modellers could return to their university offices to prepare for the next meeting.

Preparing to model between the first and the second competency group meetings

In the time between the first and the second meetings in Pickering the modellers were preparing information for working with CRUM2D. They were also developing a modelling tool that would be useful to the CG, drawing on the work done with data in the Matlab(8) programme to prepare for running CRUM2D. One part of this tool was a new algorithm that allowed the area contributing to the flow in a cell to be drawn from a seed cell: for example, starting with the cell representing the Ings Bridge gauging station it would outline the whole catchment. The algorithm was tracing the flow back uphill, resulting in a calculated catchment size that corresponded with the official map, which served both as a confirmation that the algorithm worked and as a way to discern differences. The tool simply dumped one inch of rain on a wet catchment; there was no dynamic modelling of the hydrological processes affecting soil moisture. The modellers thought that this tool might help to open up uncertainties for

(7) For information about this programme see: http://www.relu.ac.uk

(8) Matlab, a high-level language and interactive environment, widely used in universities is developed and marketed by The Mathworks (http://www.mathworks.com).

discussion and provide a 'feel for numbers' among the group members. They considered it to be a demonstrational device, something that provided a connection of data with theory and thereby a tool that could be pedagogically useful in the CG.

This work differed from the 'behind the scenes' work of modellers in PM as described in the literature. In PM, modellers parameterise the options suggested by stakeholders and run models to create scenarios, the focus being on presenting the outputs of models in the participatory forum (Voinov and Bousquet, 2010). In contrast, the focus of the project team modellers was to create a computer tool that the participants in the CG could use together in a collective research session [as an activity in which people use the model to learn about flooding in the locality this is different from the use of models in the role playing game events staged in ComMod projects (cf Castella et al, 2005)].

The second meeting—becoming the Ryedale Flood Research Group

At the start of the second meeting, the facilitator raised an issue that had become apparent in the feedback process: 'what to call everybody'. After a brief discussion, with contributions from both local participants and the research team, it was agreed to name this group the 'Ryedale Flood Research Group' (RFRG), and that this term included both academics and local participants because, as a local resident said, "We are all part of the same thing."

In this meeting the group worked with large printouts of the EA's indicative flood maps—Ordnance Survey (OS) 1:25 000 maps showing the outlines of places liable to flooding—created by engineering consultants using standard hydraulic models. Divided into two break-out groups, participants first took on the task of adjusting the flood outlines on the maps against the experience of floods among local members. In this activity individual knowledge about flooding in Pickering was made explicit and elaborated in discussions as people compared and debated their memories of flood events. Second, the maps were used to place imagined interventions that could possibly mitigate the flood risk. Everybody was encouraged to be speculative and make suggestions, without any consideration of technical feasibility or costing.

Two priorities emerged from the deliberations in this meeting: first, an interest in exploring the possibility of holding water back upstream by using low-impact, low-cost, dams as flood-storage measures. Second, the question of how much flood risk reduction could be achieved through improved river maintenance, cutting vegetation on the banks and in the river, and dredging. The final report from the engineering consultants commissioned by the EA had also looked into these issues. It presented an analysis based on FEH assessments and an ISIS routing model, summarised and considered with various interventions (EA, 2003). One upstream storage solution was modelled using a combination of three methods: first, a priori estimation of the required reduction in runoff volume to eliminate flooding at Pickering; second, modelling the effects of two reservoirs in the upper catchment using the FEH unit hydrograph rainfall–runoff methodology; and, third, combining the modelled outflow hydrographs with and without reservoirs and routing them downstream to estimate flows at Pickering. The only option considered to provide sufficient risk reduction was flood walls.

The suggestions for measures arising in the RFRG were based on knowledge about the catchment rather than model capacity. Working with maps in different ways is common in participatory environmental research (cf Golobic and Marusic, 2007, Ramsey, 2008, Yearley et al, 2003). In the RFRG it was an initial step, prompting efforts to model processes not represented in the models used to generate the maps. The group did not know which, if any, of the ideas it would be possible to model: that was something the project modellers would have to explore after the meeting.

Working on the model away from the RFRG, November 2007 to January 2008

In spite of encountering some difficulties with the rainfall radar data from the Met Office (lacking the code to open the most recent file format) the modellers expected to be able to start running realistic simulations with CRUM2D very soon. When the model was up and running, the research would progress rapidly and they would be able to do runs with different parameters, applying flat (ie spatially uniform) rainfall to the catchment. They would be able to compare runs with rainfall radar data to runs with flat data for calibration, hoping to get a better fit of predicted (modelled) runoff with that observed. However, the second meeting had brought to the fore the idea of using multiple upstream dams as storage areas, but CRUM2D could not represent these, so even when it worked the modellers would have to do some recoding. Hence, they simultaneously continued to develop the simple modelling tool created for use in the group, to begin to determine how much the flood peak needed to be reduced by and for how long, to protect Pickering. In the process they used the group's blog to ask for information about when the water reached different levels in Pickering.

The need to model small dams prompted further development of the new flow-routing algorithm. Written as a simple tool after the first meeting, connecting data with theory ('data-theoretic') for the group, it developed into a model. Emerging as an unexpected side-effect from preparing to model with CRUM2D, this data-theoretic model taught the scientists things about the catchment and raised interesting questions about model philosophy. In preparing for the next meeting with the RFRG the data-theoretic model came to take centre stage, because it enabled exploration of the effects of small dams (called 'bunds') upstream in the catchment, which CRUM2D could not do. In constructing this simplified tool, the modellers envisioned the bunds as low earth embankments. Each structure would have a 'base escape': that is, a means for continually letting some of the flow through, up to a critical limit. When the flow increased beyond the critical discharge, the rest would be held back and begin to fill the storage area behind the dam. Bunds in a series would fill up, overtop, and so on, and together they would delay the arrival of the water in Pickering. The computer model would show how the storage identified filled up and if it would keep enough water back for sufficient time. It would also be possible to explore how long water would take to travel through the catchment.

This data-theoretic modelling tool required numerous manual operations to run. To try out suggestions for bunds in various places, the modeller needed to find the grid cells in the model corresponding most nearly to the map coordinates by examining an OS map of the area as a suitable site for the structure, then work out the location of the main river channel cell where the escape flow culvert would be located. This was done by raising first the grid cells representing the approximate location, then focusing more tightly on the exact grid-cell location for the centre of the structure: that is, the one in the middle of the bund, sitting directly over the channel. It was then necessary to mark out manually which cells, to either side of the centre cell, would form the 'wall' of the bund, stretching to either side of the channel across the floodplain. Once these cells had been identified, their elevations could be reset to that of the top of the bund, and a pit-filling algorithm could then be used to calculate the filled surface behind the bund and its areal extent, approximating the surface of any ponded water when the bund was full. By subtracting from the ponded surface elevations the unfilled elevations, a calculation was made of the potential storage volume behind a bund of that height. The modellers put substantive effort into making implementation and execution quicker, so that the model could be employed to test a wide range of solutions at the RFRG meeting.

Developing the data-theoretic model into a tool that the extended research collective could use together differs from the work modellers do in PM (including ComMod) in focusing on making a scientific tool for use by lay people. Accounts of PM and ComMod projects show the numerical modelling of the physical system to be less central in the participatory events and more settled, while inventions occur in the modelling of social factors (cf Gaddis et al, 2009). The CG modelling was orientated towards making physical modelling a shared activity, shifting the focus of the knowledge-generating process from output to process. That the CG modellers chose to allocate substantial effort to getting what they considered to be a simple pedagogical tool ready for the meeting expressed their attachment to the extended research collective. In the time between the second and third meetings in Pickering their work turned towards the needs of the RFRG, rather than towards providing input to the scientific modelling of the catchment in CRUM2D.

The third meeting in Pickering

In the third meeting the RFRG worked with the data-theoretic model running on laptop computers, making it possible for the group to explore how much flood reduction could be achieved by upstream storage. The tool made it possible to put bunds of different heights on river reaches in the upper catchment to see whether they would make a difference to the flow through town, under circumstances that would normally lead to flooding. With this model, the RFRG could collectively think through where there might be opportunities for storage, as well as possible constraints (such as the tracks of the North Yorkshire Moors Railway). The video record of the meeting shows how the visualisation of possible situations, provided by the model, enabled discussion of ideas, concerns, and criticisms in the group. The model results were not simply taken as given, but were central in a critical engagement with modelling in general, the specific case of Pickering Beck and the model that the group was using to understand it. The criticisms aside, the group developed a majority consensus that upstream storage might be used to reduce flood risk for Pickering at relatively low cost. In this meeting the model became an object that all members of the extended research collective connected with. Although it was the scientific modellers who had the skills to create it, the way it worked and how to interpret its output were understood by all group members. The model came to embody the expertise developed in the extended research collective, and it facilitated the thinking through of the flood problem in Pickering in ways not previously possible.

The scientists perceived of the work in the RFRG as different from their usual practice. Reflecting on the third meeting one modeller said:

> "I think what we actually let happen here, was we let the science question be framed by the competency group, not by my understanding of what is important about rural land management and flood risk. And that is what we do. We follow that. We don't say 'oh yes but there are all these other science questions we must open them up and steer them in that direction'. And that is what is different about where we have gone."

Modelling after the third meeting

The modellers were pleased with the way in which the data-theoretic model worked in the RFRG. They found it interesting that using the model in the group had brought knowledge forward in new ways and had brought up memories, for example, that the railway is partly built on bales of wool and about the channel-bed materials. However, there were some things they wanted to add to the model—making it calculate convergent reaches with bunds in different places and making it calculate the speed of the water (flow times) under different rainfall conditions and different bunding combinations.

In the version of the model used in the meeting the bunds had to be put in a specific order and only in contiguous reaches. The modellers were going to rewrite the code so that bunds could be put into converging reaches, in any order. For the next meeting they aimed to have flood delays and rain distribution in the model. They also hoped to be able to make the model easier to use.

After the third RFRG meeting the modellers decided not to use CRUM2D. They had realised that it would not be possible to adapt it to work with the questions that the RFRG had decided to prioritise within the existing timeframe. Instead, they opted to focus on the data-theoretic model used in the group. This was also a good idea since the long 'spin up' time (100 days) needed for CRUM2D was not necessary for the purpose of estimating flood risk. They only needed to model a few days before and after a flood event. In this case writing a new model would be a way to incorporate new algorithms, truncate the simulation timeframe, and speed up the modelling process. In addition, it would not require working new routines into CRUM2D to represent the bunds. This decision marks an important dissociation from their expected trajectory. Rather than adapt the RFRG agenda to fit the existing modelling approach, the modellers opted to develop the science to advance the RFRG's objectives. In doing this they could not be certain that the model they would end up with would actually work, as one modeller said about the data-theoretic model:

> "What this tool gives us is a point to start from. Now it may be that after the checking, it turns out it doesn't work."

This type of shift in research plan is not described in the literature accounting for planned participatory research. However, when challenged by lay people in controversies, scientists have been shown to change their approach: for example, in AIDS research (Epstein, 1996), or regarding the impact of radioactive fallout on Cumbrian sheep farms (Wynne, 1996). In the context of the CG experiment, the dissociation from the extant model occurred without conflict. It just turned out not to be the best tool for the RFRG and the scientists' ambition was to contribute their knowledge and skills to the collective process. The modellers' aim was to bring an improved version of the data-theoretic model to work with in the fourth meeting. However, this meeting took a different turn and in subsequent meetings the group focused on other aspects of the issue of flood risk in Pickering, among other things using an extant model to explore the impact of river maintenance on flood risk. The model was not tried out further in the RFRG, but it took on an existence outside of the group.

The 'bund model'

As planned, the modellers presented the approach to a scientific audience at an international conference, where they introduced the idea of data-theoretic modelling and showed how the development of the new model had involved a much broader definition of the category 'data'. They encountered some resistance amongst the audience towards broadening the term in this way, as well as the view that the only kind of knowledge that should be admissible in hydrological models is that which is physics based. Faced with peer criticism the modellers chose not to separate the work they did in the CG from their 'scientific' activities. Instead of defining the RFRG experience as a one-off public engagement activity, they persisted in advocating the value of the process for advancing science. They used the criticism constructively, adopting the label 'knowledge-theoretic' instead of 'data-theoretic', considering the former more appropriate for capturing the nonstandardised information generated in the RFRG. They rejected the suggestion that the information used in modelling should be constricted, insisting instead on the value of multiple sources of varying types (Odoni and Lane, 2010).

Participating in the CG had led the scientists to shift, from advocating the kind of physically based model represented by CRUM2D to advocating, defending, exploring, and working with the bund model produced through the RFRG. They started to talk about the assumptions necessary for the bund model to work, such as that, in extreme events, the catchment was nearly saturated. They looked at the data to test that this was indeed the case for the 2007 event. They thought about what would need to be done to show that the model was reliable. In other words, they demonstrated an attachment to the new RFRG-originated model and this transformed the work that they were doing. To gain further trust in what the model seemed to be saying, they went back to some of the original consultants' reports. These reports seemed to question the assumptions that the model was making about the size of the 2007 flood peak and, momentarily, this shook the modellers' faith in what they had done. However, the ultimate arbiter became the RFRG, as the modellers took the problem back to a meeting in May 2008. Local participants were able to resolve the concerns regarding the reliability of 2007 flow estimates because of their knowledge of how a local farmer modified the river section that was being used to produce the estimates.

The bund model was presented to a wider public at an event held by the RFRG in Pickering Town Hall in October 2008 to publicise its work. Approximately 200 people visited the event at which the model was demonstrated as one of the outcomes of the CG process even though, at that point, it had not been validated in conventional scientific terms. The event and the outputs of the extended research collective—the bund model and a written report—were well received in the local community and by the institutions responsible for flood risk management. The bund model was taken seriously by the EA and it contributed to new efforts to solve the problem of flooding in Pickering (see EA, 2009a; 2009b).

Conclusion: from local 'participation' to 'coproduction'

Although CG is not a PM or ComMod method, the way in which the RFRG developed connected this particular experiment with these ways of involving local residents with environmental modelling. This CG, staged in the midst of a controversy over flood risk management in Pickering, shows how computer simulation modelling can be employed to further a civic rationale in public engagement, so as to produce a more democratic science. Compared with PM and ComMod which aim to democratise computer modelling by bringing stakeholder knowledge into existing institutional orders and to aid stakeholder collaboration, the CG approach introduces a critical dimension in participatory modelling.

The aim of redistributing expertise, as configured in local controversy, underpinned the work of the natural scientists in Pickering. This aim sets CGs apart from other public engagement activities which "nearly always [impose] a frame which already implicitly imposes normative commitments—an implicit politics—as to what is salient and what is not salient, and thus what kinds of knowledge are salient and not salient' (Wynne, 2007, page 107). In contrast the CG methodology prompts the extended research collective in the affected locality to define what knowledge is important. In Pickering this approach to public engagement showed the viability of working with self-selected, nonrepresentative, local residents on a controversial issue.

Two features critical for the redistribution of expertise depend on the willingness and ability of the participating scientists: the dissociation of science from the institutions that have become embroiled in controversy and its attachment to an open-ended research agenda. Reflecting on the process, the scientists participating in the CG in Pickering noted two important changes in their practice. First, the modelling work involved a framing that came through the group and rapidly supplanted the scientists' own initial framing. They were forced, from the beginning, to innovate in their modelling approach so as to deliver the evolving goals of the RFRG. Second, rather than the RFRG constituting an impediment to their scientific responsibilities in developing new modelling tools, they found that it had enriched the process and actually made it easier in some senses. It had brought to their working a new sense of 'moral imagination' (Coeckelbergh, 2006) in which the material experience of flood risk and the need to reduce it became bound up with their day-to-day activities, rather than bolted onto the end.

In this paper we have mapped the experience of the scientists. Using the notions of 'dissociation' and 'attachment', we focused on connections: how institutional ties to science and organisations were loosened while new relationships with people and things in a particular locality were created. Although this is only one case, we do think that some degree of dissociation and attachment reconfiguring the commitments of scientists is necessary for participatory modelling to realise a civic rationale. In the case discussed here, the new attachments shaped the knowledge that emerged, in the form of the bund model, to which the scientific community and the management organisations the scientists had dissociated from, could later relate. This new model became pivotal in the controversy whose energy had forged it. New alignments and agendas could form as science was mapped into local knowledge. The bund model is not intended to replace extant models, but it was a better tool in Pickering than the standard modelling approaches because it enabled the opening up of the stalled local controversy. Emerging as a consequence of pursuing the RFRG agenda, the bund model, fashioned to answer the questions that the group had decided were important, could travel from the group to flood risk management and to scientific discourse, as demonstrated in the EA's uptake of the bunding idea and publication in the scientific literature (Odoni and Lane, 2009). All models simplify, but the decisions about what to leave out depend on the framing of the problem rather than any independent, objective, set of criteria. Most model development is done with framings that tend towards the general rather than the particular. In the previous modelling of Pickering, as is the standard for modelling flood risk in the UK, the models used were developed to be general, to work in any location, for answering every question. This was not the ambition of the bund model which aimed to generate new knowledge about the particular locality.

The CG methodology relies on controversy to prompt local residents to engage with science. The research in Pickering shows that CGs can bring scientists and members of the public together in a way that enables coproduction of knowledge. This is a form of democratisation different from the representation of stakeholders in the environmental decision-making process addressed in other participatory projects. CGs aim to intervene in the generation of knowledge in situations when existing knowledge does not suffice. Being open-ended it is impossible to predict or control the outcome of a CG. Hence, it cannot be formulated as a generally applicable method to solve a type of problem. Successful CGs have unanticipated outcomes. This makes them risky as well as critical with regard to existing institutional arrangements. Their appeal is to scientists and/or local communities critical of existing embroilments of science and environmental decision making.

Actualising a 'civic' rationale for public engagement, enabling science to become relevant to local matters of concern, will always generate outcomes unanticipated by established experts and institutions. Whether and in what ways knowledge produced in such 'extended research collectives' impact on local environmental controversies will vary, but, in situations where all action seems impossible, creating an intellectual space and involving scientists in a locally relevant manner can be an important first step.

When existing scientific knowledge does not suffice, CGs may be of benefit to local environmental management, as in Pickering, where the cost of recurring floods, ongoing controversy, and a lack of a way forward meant that the competency group made a positive difference for those concerned about flooding in the town.

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