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Opportunities and Challenges to Increase Inter- and Transdisciplinarity: A Qualitative Study of the FloodRISE Project

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Background: The FloodRISE project, which started in 2013 in Southern California, aimed at better understanding how to promote resilience to coastal flooding. It was based on a cross-disciplinary approach, involving several research teams and local communities.

Purpose: We conducted a qualitative study of the first phase of the project (2013-2015) in order to analyze its inter- and transdisciplinary aspects.

Setting: We conducted this evaluation as a visiting postdoctoral researcher at UCI, not participating in the FloodRISE project.

Intervention: Not applicable.

Research design: We conducted 18 semi-structured interviews with members of the three project teams—modeling, social ecology and integration & impact—at UCI in 2015. Data were analyzed and interpreted to identify key aspects of the collaboration within and between project teams, as well as their relationship to local stakeholders.

Findings: The analysis showed that an intensive *dialogue-based* method of interaction and the presence of *boundary researchers* played a fundamental role in bridging the conceptual and methodological gaps between social and engineering sciences. These results thus exemplify several possibilities for developing more efficient interactions between researchers in a cross-disciplinary project. However, any cross-disciplinary project should: carefully evaluate potential for participants to become boundary researchers, since participants with multiple disciplinary expertise may be underemployed; improve researchers' level of readiness, in order to facilitate further interaction and increase time efficiency; and clearly address remoteness issues to avoid lower collaboration between central and peripheral locations.

Keywords: *interdisciplinarity; transdisciplinarity; qualitative study; project evaluation; flood risk*

Introduction

For a few decades now, the use of cross-disciplinary approaches has been advocated to tackle complex issues in a number of fields, including climate change or public health (Lawrence, 2010). Cross-disciplinarity covers a wide variety of approaches, ranging from multidisciplinarity, to interdisciplinarity and transdisciplinarity.Whereas interdisciplinarity aims at going further than the simple juxtaposition of disciplines that tends to define multidisciplinarity, notably by allowing a dialogue between disciplines, thus fostering the emergence of common concepts (Ramadier 2004), transdisciplinarity tries to go beyond disciplinary boundaries, promoting collaboration among a hybrid mix of actors from different disciplines, professions and sectors of society (Klein, 2004), a definition sometimes referred to as a "European conceptualization" (O'Rourke, Crowley et al. 2014: 4). We insist on this characterization of transdisciplinarity as "the co-production of research with non-academic stakeholders" (Lyall, Bruce et al., 2011: 14) since other definitions tend to conceptualize it as a "deep interdisciplinarity," emphasizing the *integration* of researchers' work, by opposition to the *interactive* process of interdisciplinary research (Stokols et al., 2008). In that regard, academic research projects may include inter- and transdisciplinary components.[1]

According to Barry and Born (2013), the use of inter- and transdisciplinary approaches can be based on different types of interaction between academic disciplines and pursue various objectives. Concerning the relationship between disciplines, they notably distinguish between an "integrative" mode where symmetry between disciplines is more or less achieved, in opposition to a "subordination-service" mode, in which one or several disciplines are dominating, typically observed between natural and social sciences, the latter being subordinated to the former. Regarding objectives, they identify three "logics". First, "accountability" refers to the idea of cross-disciplinarity triggering more public understanding or participation. Second, "innovation" insists on the potential of cross-disciplinarity in shaping new concepts, methods or practices. Third, "ontology" insists on how cross-disciplinarity can produce novel, or hybrid, scientific objects.

Ideally, considering these aspects—the mode of interaction between disciplines and the type of objective that will be followed—should represent the very first phase of any consistent cross-disciplinary project. Indeed, several frameworks describe best practices to avoid or solve potential research concerns that may arise from the use of cross-disciplinary approaches. For instance, Tobi and Kampen (2018) used a model based on conceptual and technical designs, and specifically dealing with integration and ethical issues related to the collaboration of natural and social scientists. Proposing another approach, König et al. (2013) emphasize the importance of nurturing an "interdisciplinary culture" through the use of "mentors" and "facilitators" early on in the project.

However, what would happen if a research team were not following those prior steps? How much of the success of a cross-disciplinary project lies in its level of preparedness? So far, very little attention has been devoted to projects where improvisation and flexibility play key roles.

In order to investigate the impact of a low level of readiness on the outcomes of a cross-disciplinary research, we will analyze the FloodRISE (Resilient Infrastructure & Sustainable Environments) project. This project aimed at promoting resilience to coastal flooding in Southern California. Indeed, with 1,100 miles of shoreline, California is increasingly vulnerable to flooding disaster, especially in lowlands areas accounting for about 28% of its length, such as beaches or estuaries (Griggs, 2010). Factors including sea level rise and global climate change call for new adaptation strategies, bringing together not only academic expert from various disciplines but also local knowledge possessed by stakeholders ranging from residents to civic leaders and practitioners. The project relied on the

[1] To avoid confusion, we will use the term "cross-disciplinary" to describe projects that can possess an inter- *and/or* a transdisciplinary component.

collaboration between three research teams in social ecology, modeling, and "integration and impact," gathering more than 20 scientists working on two case studies: Newport Beach and the Tijuana River Estuary. Most of the scientists worked at the University of California, Irvine (UCI), although three researchers dealing with economic issues were located at the San Diego State University (SDSU) and two members of the "integration and impact" team worked at the Tijuana River National Estuarine Research Reserve (TRNERR). Funded with $2.8 million by the National Science Foundation (NSF) for a period of 4 years, from 2013 to 2017, the FloodRISE project offers interesting insights into ways of overcoming challenges and obstacles faced by cross-disciplinary projects.

This paper aims at describing and analyzing how the research teams collaborated during the period considered (2013-2015) and what were the main factors stimulating or hampering the cross-disciplinary potential of the project[2]. First, we start by introducing some key challenges faced by cross-disciplinary projects. Second, we present the conceptual framework used to analyze the FloodRISE project, dividing cross-disciplinary collaborations into three phases: antecedents, process and outcomes. Third, we briefly describe methodological aspects of our qualitative study. Fourth, we give an overview of our main findings for each of the conceptual phases mentioned above, insisting on the evolution of researchers' collaboration throughout the project. Finally, we discuss the implications of our findings regarding the importance of predesigning cross-disciplinary features of such a research project.

Inter- and Transdisciplinary Challenges

Interdisciplinary Challenges

Interdisciplinary research projects are consistently dealing with the task of integration. Whether it is about concepts, theories, methodologies, results or even physical interaction (when distance between team members is an issue), "the greater the level of integration desired, the higher the level of collaboration required" (Klein, 2014).

Given their collaborative nature, interdisciplinary research projects tend to face specific challenges, notably in terms of problem framing and integration of results. Problem framing consists in defining the problem under study, figuring out possible solutions to it and identifying resources needed to do so (Stokols et al., 2010). Problem framing issues are thus especially at stake when various research teams have to reach a shared vision of the problem they study and of the objectives they pursue. The more distant researchers' scientific backgrounds are, the more complicated it is to achieve this common ground, for instance between natural and social sciences. On the contrary, interdisciplinarity taking place between similar disciplines appears less constraining. "Weak interdisciplinarity" thus corresponds to the situation where disciplines agree on the same "pre-discursive identity of their object or subject of study," whereas "strong interdisciplinarity" occurs when such a consent is not granted (Gethmann et al., 2015).

Developing integrated results refers to the capacity of the research teams to produce common rather than simply juxtaposed results, thus ensuring their collaboration has meaningful and tangible outcomes and is capable of building a synthesis (Defila et al., 2006). Of course, successful collaborative problem framing and integration of results implies to overcome certain obstacles. Firstly, the specific nature of an interdisciplinary project has to be acknowledged from a theoretical and methodological perspective. Secondly, the ambiguous role played by disciplines within such a project has to be taken into account. Indeed, the strength of an interdisciplinary project is not to ignore disciplines but rather to allow various "substantial disciplinary contributions" in a cohesive way (Stokols et al., 2010). Yet "disciplinary socialization" is prone to

[2] This paper is based on a study conducted while being a visiting postdoc at the School of Social Ecology at UCI. The research and interviews were done in accordance with the project directors and followed UCI Responsible Conduct of Research guidelines.

"centrifugal tendency" and "fragmentation", the more specific disciplinary identities are, the harder it becomes to bridge the gap between them (Stokols et al., 2010). Strong disciplinary commitment thus appears to be a sine qua non condition of any interdisciplinary research and, at the same time, its main obstacle.

Transdisciplinary Challenges

Since transdisciplinary research projects can bring together very heterogeneous stakeholders with decision-making power (for instance private companies, public authorities or civil society organizations), one of their main concerns is to address explicitly those actors' potential conflicting values and perceptions. Referring to "the common good or sustainable development as regulative ideas" can help reflecting on ethical issues such as fairness and justice (Hadorn et al., 2010) but they do not provide definitive answers regarding best practices or policies to implement. In the case of sustainable development, numerous trade-offs are to be taken into account, for instance between present and future generations' interests or between economic, social and environmental stakes.

What is more, real-world problems tackled by transdisciplinary research are usually characterized by their high level of uncertainty and complexity. Acknowledging that the comprehension of the genesis and development of a problem can only be incomplete, especially in the face of several stakeholders, should lead to the careful design of experiments to deal with that uncertainty (Pohl & Hadorn, 2007).

Conceptual Framework

The study of cross-disciplinary projects, or science of team science, involves specific analytical frameworks, as their conceptual background, methodology and objectives are generally very different from disciplinary works. Considering FloodRISE as an inter- and transdisciplinary project—since it explicitly intends to incorporate local stakeholders' knowledge—we will thus use a conceptual model developed by Stokols et al. (2003, 2005) to structure our study of the issues at stake in terms of collaboration between various research teams. This model is divided into three parts: antecedents, process and outcomes. Antecedents include intrapersonal factors, physical environment, as well as organizational and institutional features. The collaboration during the process stage is influenced by intellectual and interpersonal factors, while cross-disciplinary outcomes are evaluated in terms of new concepts and training programs, institutional changes and innovative policies (see Figure 1). Each phase logically has an influence on the following one. For instance, participants' individual characteristics contribute to shape their eagerness to further collaborate during the research project itself and the quality of participants' exchanges determines, in turn, to what extent the project outcomes can be innovative. What is more, outcomes should also be considered as potentially influencing both "antecedents" and "process" steps, since a successful project might notably trigger institutional or organizational changes or foster renewed collaboration between participants.

Coming back to research challenges highlighted before, problem framing issues are typically related to the antecedents and process parts. For instance, researchers' academic backgrounds would be described as intrapersonal features (antecedents) and the proximity of their respective disciplines as interpersonal characteristics (process). On the other hand, the integration of results mostly deals with the outcomes part. In this case, a successful collaboration would for example produce *integrated results* in the form of new concepts or innovative policies.

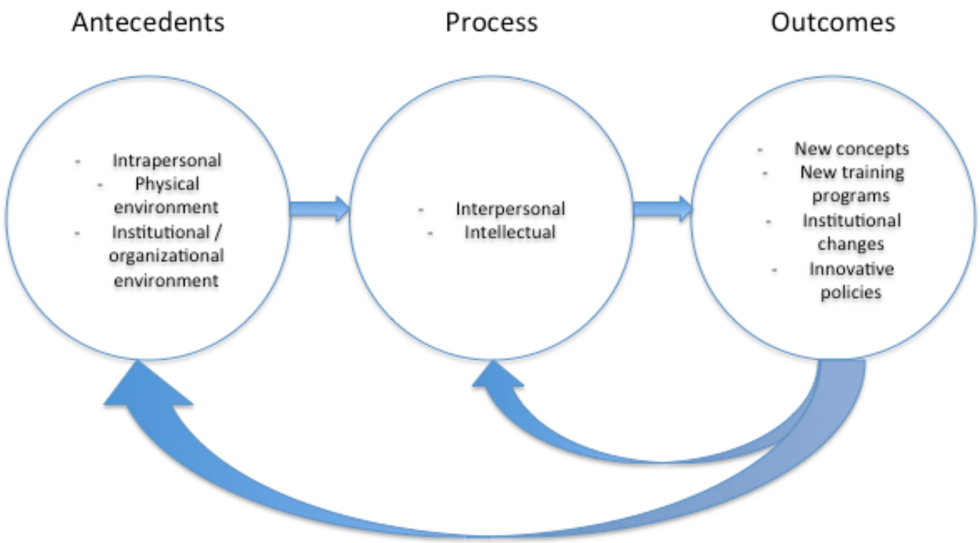

Figure 1. *Conceptual framework of a cross-disciplinary collaboration, based on Stokols et al. (2003).*

Methods

We conducted 18 semi-structured face-to-face (14) and phone (4) interviews with project team members (out of a total of 22 members) between May and September 2015: 8 from the Social Ecology team based at UCI, 5 from the Modeling team based at UCI, 3 based at SDSU[3] and 2 from the Integration and Impact team (see Figure 2). Interviews lasted between 30 and 50 minutes. We had no working relationship to the interviewees. The interview guide comprised a first set of questions related to the researchers' personal background. A second series of questions was devoted to interdisciplinary issues such as their perception of the collaboration within their team *and* with the other research teams. The last group of questions was dedicated to researchers' interactions with local stakeholders and their conception of scientific knowledge vis-à-vis potential societal impacts of the project. We recorded and transcribed all the interviews. We then analyzed the transcriptions using *ATLAS.ti* in order to identify common or antagonist participants' perspectives on key issues of the FloodRISE project. Transcriptions were mainly studied through the use of "quotation" and "coding" functions, each interviewee's quote relevant to a certain topic being associated with a specific code (for instance, "interdisciplinarity"). This process allowed us to sort out participants' responses according to the three parts presented above: antecedents, process and outcomes. Since we were neither involved in the FloodRISE project, nor had we any prior relationship to project team members, data collected helped us building an understanding of the project as well as the analysis itself. As a visiting scholar, we had a privileged position in the sense that we were not subject to potential conflict of interests that may arise when a researcher has to take a stance towards one's faculty or department.

[3] Researchers from SDSU were formally considered as part of the social ecology and modeling teams.

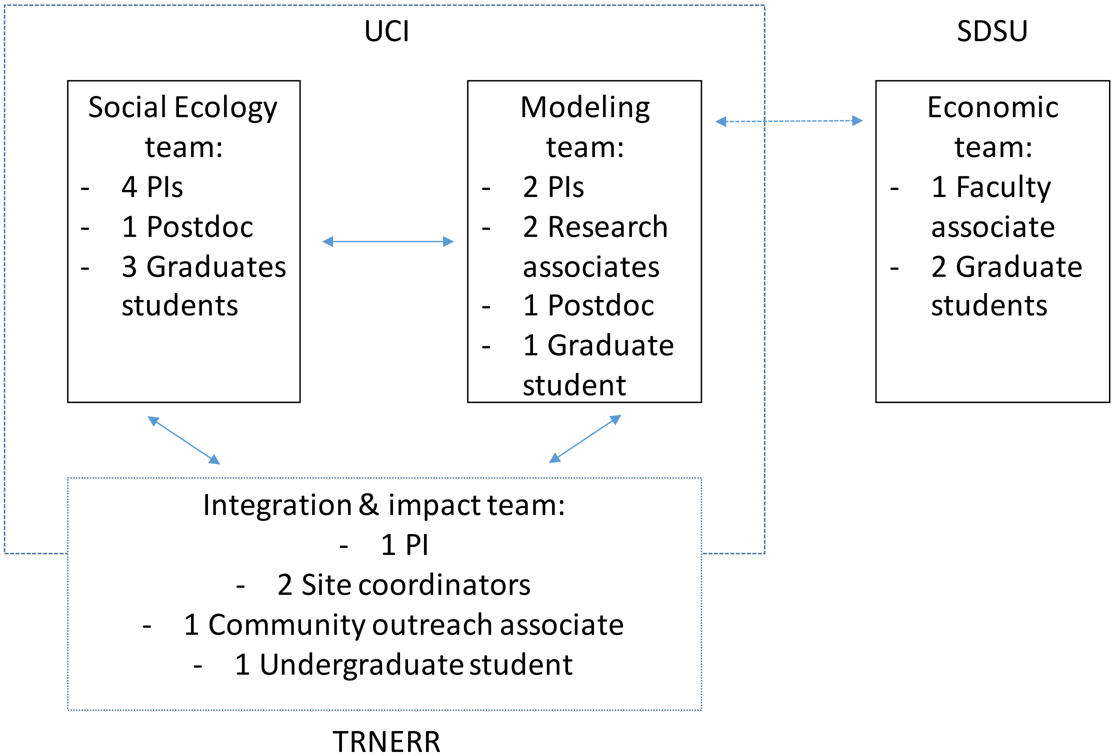

Figure 2. *Structure of the project and composition of the research teams at UCI (University of California Irvine), SDSU (San Diego State University) and TRNERR (Tijuana River National Estuarine Research Reserve).*

Results

This section presents the reflections and perceptions of the project team members, as expressed in their interviews. [4] Unless otherwise specified, our interpretation is presented in the discussion section.

Although the idea of interdisciplinary collaboration has always been emphasized in FloodRISE since it was part of the NSF requirements and because the three initial investigators belonged to various departments (schools of engineering and social ecology, as well as the Environmental Institute, later dissolved), the project has been experiencing, since its beginning, an "organic" development. Its most salient features have been the strong impact of spatial and institutional organization regarding researchers' capability to efficiently collaborate; the intensive dialogue-based method of interaction between research teams; and the key role played by some graduate students in bridging the gap between research teams and between academia and local stakeholders.

Antecedents

Several members of the modeling team had previously worked on a hydrological model of the Newport Beach Bay and acknowledged the need of parcel level measurement and fieldwork. They also had been aware of the existing gap between their modeling capacity and what they were able to communicate to stakeholders, thus their interest in adopting a more interdisciplinary approach and to work in collaboration with social scientists. The fact

[4] Whenever interviews are cited, quotation marks are used.

that initial principal investigators (PIs) were acquainted largely determined their collaboration on the NSF project proposal.

Knowledge of multi-, inter- and transdisciplinarity. Globally, researchers did not seem to have a precise idea of the concepts of multi-, inter- and transdisciplinarity, nor did they share a common understanding of those. Even when a participant had a broad definition in mind, it did not imply he would use those concepts in his daily research activities. Such concepts were rather "inherently" used. Some participants would consider the project as multidisciplinary, while others would describe it as interdisciplinary or even still very much disciplinary. Transdisciplinarity was usually deemed very abstract by nature, representing the "Holy Grail" of scientific inquiry and being certainly out of reach of the FloodRISE project. Instead, coordination was "naturally" managed by researchers who "knew where to go", notably the head of the integration and impact team. The idea that collaboration involving different research teams having different scientific backgrounds implied certain requirements was not frequently mentioned. Participants did not have all the same capability to deal with an interdisciplinary research setting, notably from a scientific perspective, their background encompassing more or less the research topic. For instance, some scholars had a background in natural hazards sciences but not specifically in flood hazard, others were specialized in modeling of natural phenomena, not necessarily in modeling of flood, etc. They had thus to spend more time on getting familiar with the research topic. Certain participants insisted on having an interdisciplinary background, notably those having studied urban planning.

Spatial location. The fact that researchers from the social ecology and modeling teams were located within a five-minute walk from each other on the UCI campus played a significant role in their ability to meet on a regular basis, especially in the case of the graduate students and postdocs in charge of the two sites. Accordingly, the remoteness of UC San Diego was a major drawback regarding a deeper involvement of the economic team, this isolation being exacerbated by their disciplinary difference vis-à-vis the social ecology team. This geographical isolation was also reflected in the fact that (almost) every researcher went to the Newport site, whereas very few went to the Tijuana site.

Institutional organization. Interestingly, the coordinator of the project was not located in one of the departments participating in the project but seated instead in the Sustainability Initiative whose aim was to promote interdisciplinary projects and education programs on sustainability at UCI. In consequence, the coordinator was academically free to go back and forth between the various research teams, "working for everybody and at the same time managing everybody". Given the fact that the coordinator also belonged to the impact and integration team and was the Newport site coordinator, this team was regarded as a "boundary group", playing the role of an interface between research teams and between UCI and local stakeholders.

Objectives. The first phase of the project was mainly dedicated to the conduction of a survey among local residents in both sites, even though Newport Beach was clearly intended to be the first site to be studied, notably because of its proximity to UCI ("lower hanging fruit"). The overall objective was to "integrate the perception of [flood] risk with the actual [environmental] risk", comparing discrepancies between the two, and to generate a flood-mapping tool to inform stakeholders about flood risk. A comparison of existing online flood-mapping tools was also undertaken.

Researchers had various objectives they regarded as the main reason why they participated in the project. To some of them, having an influence on community development and policymaking was essential. The sense of community belonging was especially significant for participants having spent their life close to the study sites. To some others, the goal was to contribute to science in their field. Some would also express their wish to fulfill their interest or passion for environmental issues. FloodRISE also represented the dissertation topic of several graduate students for whom conducting research for their thesis was the main objective. Faculty members seemed more concerned with publications, notably because of funding agencies' expectations, and graduate students with gaining research experience and potentially having an impact on the field.

What is more, objectives between the social ecology, impact and integration and modeling teams seemed to be incongruent, the latter being more focused on publications, sometimes at the expense of the "long-term community-based efforts to ensure the broader impact". In this regard, the extent to which the project was constrained by academic needs is unclear and whether it will be capable of delivering broader social outcomes, corresponding to initial expectations, remains uncertain. This is largely because researchers are awarded for their academic work, not for their "community impact". On the other hand, concerns were raised about the compatibility between research objectives and "consulting" tasks, the latter being more technical and not necessarily academically relevant.

Process

Dialogue-based method. Meetings played a central role in sustaining regular interaction between the various teams. At a strategic level, heads of teams, as well as the chief coordinator, met once a month. Team meetings (within each team), joint meetings (between the teams) and annual retreats also took place on a regular basis.

FloodRISE gathered an important number of researchers, including six PIs. Their capacity to fully get involved into research activities was often at stake given the fact that FloodRISE was usually one of their numerous research commitments. This led to collaborative issues not only between them but also, in some cases, between them and their respective teams, notably in terms of workflow.

Participants clearly stated that, through an iterative process of communication based on meetings and presentations, mutual understanding followed a learning curve and went better over the course of the project. Meetings between the social ecology and modeling teams were especially numerous during the initial phase of the project. On occasion, members of the social ecology team would also attend modelers meetings and vice versa. As researchers got to know each other, direct communication between them tended to replace formal meetings. The positive perception of this learning curve may be linked to the relative absence of any prior set of explicitly shared understanding and objectives among researchers of the three teams. For instance, lack of communication during the early stage of the project between the three teams may be held responsible for some concerns regarding the way the survey was conceived. Indeed, it was mainly designed by the social ecology team with a liaison in the modeling team, rather than truly co-designed. FloodRISE also produced increasing returns by enhancing researchers' collaboration in other venues, such as "Water UCI", a large research initiative dedicated to water related issues in the fields of technology, management and policy.

On the other hand, the wide collaboration that took place between the different teams, notably during all-hands meetings, appeared to be more time consuming and less efficient (sometimes even "boring") than disciplinary meetings. From the modelers' perspective, more time had to be dedicated to explain basic notions or the way models were working, although engineers' task was initially to "translate a specific terminology rather than simplifying it and explaining what the models can or can't do". PIs also had to take on numerous administrative tasks and participate in very frequent meetings. Due to the large amount of people involved in the project – up to 40 people during the survey, including approximately 20 undergraduate students, 10 graduate students and 10 faculty members – scheduling was a "serious challenge". For the busiest researchers, this represented up to 50 meetings in 18 months.

Boundary researchers. Most of our participants emphasized the key role played by two graduate students belonging to the social ecology team regarding collaboration between the research teams and between those teams and local stakeholders. The first of those graduate students had taken classes in engineering sciences and GIS and served as a strong liaison between social ecologists and modelers, translating engineers' terminology to the social ecology and outreach teams. The second one had previously worked with stakeholders linked to the Tijuana river estuary and had a very good "prior knowledge" of local issues. This graduate student was actually largely responsible for the adjunction of the Tijuana site to the project.

The collaboration with modelers was considered as positive. Both the postdoc in charge of the Newport site and the graduate student in charge of the Tijuana site were deemed very receptive to work with social ecologists.

In the same vein, a graduate student of the economic research group had the task to train the two other members of the group to use GIS tools, in order to deal with the survey data. However, graduate students in the economic group did not have any contact with other teams, with the exception of a meeting they had with modelers, leaving them doubtful about the potential of interdisciplinarity.

Local stakeholders. The idea underpinning the need to refer to local knowledge was that general flood models based on national data might tend to overestimate the impact of sea level rise by not considering the way that communities adapt to those impacts, notably with infrastructure. Even though it is interesting to note that residents did not systematically increase their protection against flooding but sometimes reduced it, as in the case of Newport Beach where residents made holes in seawalls to reach docks more easily.

One of the biggest challenges faced by the modeling team, regarding information they could gather through their iterative interaction with stakeholders, was that local knowledge was not necessarily spatially located and thus more complicated to integrate into models. The survey thus innovated by asking local residents to show on a digital map where they believed there was a flood risk. To ensure the smooth running of this part of the survey, the social ecology team had one supervisor for methodological and conceptual aspects related to mapping tools.

The potential for stakeholders to benefit from fine-tuned models was deemed considerable by the project investigators. The necessity to co-design those models by considering not only what science says but also what were stakeholders' needs was emphasized. For instance, a visual representation of flood depth based on a body scale instead of meters or feet units was used, in order to facilitate dissemination of results within communities. The Orange County Operation Center also provided positive feedbacks regarding the use of colors to highlight the various flood drivers represented on maps. However, since the project final results might take years before being available to stakeholders, "managing expectations" was an issue to deal with regarding people's eagerness to use those results. Engineers also had to adapt their communication tools and their language (a more "digestible format") to the public and non-experts in the field, for instance by avoiding the use of technical vocabulary or concepts such as "uncertainty bars".

Newport Beach. In Newport Beach, research teams were cautious not to get too much involved in local politics, notably regarding the "heated debate" about seawalls. Their intention was also not be too alarmist and to consider there was enough time to manage risk. Contacts between city officials and researchers remained limited to a few key people, for instance the building and flood tide manager who was already known by one of the project PIs. A member of the impact and integration team was attending the City's committees dealing with sea level rise issues, to gather information but not to inform City's representatives and employees about the FloodRISE project. The impact and integration team attended some community meetings and a workshop on sea level rise was organized in collaboration with the University of Southern California (USC) to inform local stakeholders about flood impacts. Activities were also organized on the UCI campus to inform the public about the project.

The survey itself involved 22 undergraduate students who spent 12 weeks in the field and conducted 290 face-to-face interviews lasting 40 minutes. Both local residents and researchers positively evaluated their interaction, the survey almost reaching a 10% return rate (out of a surveyed population of approximately 3000 people). Local residents could provide details about the extent of (nuisance) floods that models could usually not capture or regarding the precise contour of neighborhoods. Researchers could notice differences between newly arrived, such as students, and long-established residents in terms of "flood risk perception, awareness and preparedness", the latter assessing better the nature and extent of flood events, some of them having for instance a perception very close to scientific data, such as those provided by satellite images. Modelers could also use pictures taken by residents to better analyze flooding in the area.

The economic issue linked to real estate prices was controversial in many respects. Firstly, residents were expected to be reluctant to hear that flood risk might negatively impact the value of their property. Secondly, housing market participants did not believe flood risk was likely to become a serious problem. Thirdly, scientific evidence did not necessarily show an automatic decrease in property value in case of flood risk. Nevertheless, it was considered that cities developing flood management in collaboration with residents were obtaining positive outcomes, for instance lowering the cost of mandatory insurances residents need to pay.

Tijuana. Initially, it was unclear whether a Mexican area would be studied but when it appeared that the San Diego valley did not have enough population (only about 20 people to survey), the site was extended to include the Tijuana River Estuary. This idea was brought into the proposal by a former coastal manager at the Tijuana River National Estuarine Research Reserve, working in the social ecology team. In addition to interviews conducted in the San Diego Valley, one Spanish-speaking member of the Integration & Impact team led a group of five Mexican surveyors, who conducted 350 face-to-face interviews with residents of the Los Laureles Canyon area (Tijuana, Mexico).

In contrary to the Newport site, flood risk maps produced for the Tijuana site by the research team were similar to existing ones, thus questioning the relevance of the community-researchers interaction. However, in Tijuana too, researchers were asked not to publish anything "drafty" that could not be completely backed and remained therefore very cautious. Given the stark contrast between Newport and Tijuana sites in socioeconomic terms, researchers were also asked to be careful regarding words they used and to insist on "challenges to resilience" rather than on "risk and hazards", since the relationship between public authorities and the population was often troubled. In the San Diego valley for instance, people tended to blame the Government for flooding events.

The Tijuana River National Estuary Research Reserve knowledge about the site helped the social ecology team to better understand the local context and to refine (and translate into Spanish) the survey accordingly. For instance, the steep topography of the Los Laureles Canyon implied specific flood-related issues, which did not exist in the Newport Beach site, such as erosion and landslide. At the same time, the perception of the university by the community (residents and practitioners) on the Mexican side was slightly suspicious, especially when certain community representatives (site coordinators) were not fully involved in the research process as they did not receive notifications of coming meetings or when they were told they had been surveyed because of methodological constraints. In this regard, the relationship with stakeholders brought in by the only former practitioner of the social ecology team having some experience of the Tijuana site proved to be useful. In comparison to the Newport site, partners in Tijuana were deeper embedded locally, fostering more community engagement. A presentation was notably given to the Tijuana River Valley Recovery Team, which was composed of the various agencies dealing with flood risk in the area. However, from an academic perspective, relationship to the Tijuana site was weaker than in the case of Newport Beach, attracting less participation from PIs. For instance, only one of them visited the canyon. In that sense, only a small portion of the project team members interacted with the Mexican partners and local population.

Outcomes

Mutual exchanges within teams. Members of the social ecology team considered that their collaboration fostered new ways of thinking, thanks to the many disciplines they represented as a group, especially in the urban planning field, each researcher "having three or four disciplines in his pocket". For instance, the PIs had all (very) different backgrounds and focuses, some being primarily concerned with methodological or impact issues, while others were bringing in their expertise on specific issues, like water policy or GIS.

In the modeling team, work was relatively segmented. If the method used was developed as a group, most of the input would go from researchers who worked on the general framework to those working on the two sites, even though some raw data could be locally gathered and processed by researchers working on the general framework.

Mutual exchanges between teams. The interaction between the social ecology and the modeling teams had both material and intangible outcomes, producing some sort of "fusion knowledge". During their work on the survey, the social ecology team suggested for instance to only use red color to indicate a danger on maps and not to express random numerical values. Working in close collaboration with social ecologists also helped the modeling team to keep in mind "the broader picture of the project, which is easily lost in technology community", and how to interact with its human component, something engineers were not used to working with. The modeling team was able to assist the social ecology team in defining a flood prone area large enough to allow a sufficient population sample they could work with in Los Laureles Canyon and to fine-tune the survey according to its specific local physical and urban characteristics. In this respect, the contribution of the modeling team to the reflection about the Tijuana site was significant.

Participants also learned a lot about each other's field of research and methodology, although qualifying such input on the project outcomes is harder. The variety of participants' backgrounds, both within and between teams, was considered as very positive.

Back and forth communication was something modelers were not necessarily used to. It implied giving up, to a certain extent, control over the research process and wait for other teams' input, thus requiring more patience on their side. It also implied a "less linear" pattern of collaboration throughout the research.

However, the social ecology team did not have an influence on the development and parameterization of the models themselves. Even social ecologists with a background in engineering sciences did not have an opportunity to do so. To a certain extent, the work done remained segmented, rather than truly coproduced, in the sense that each team was responsible for its core research activities with limited contribution from other teams, the "map experiment in the survey being the extent of [their] blending". Aside from boundary researchers, exchanges between teams remained limited, leaving potential room for additional collaboration. For instance, publications in interdisciplinary journals were not really intended. Instead, engineers were more likely to use social ecology results "to frame the introduction of their papers".

Interestingly, researchers from UC San Diego who worked on economic issues, although closer from a discipline perspective to social ecologist than modelers, had more interaction with the latter. They exchanged data and their respective understanding of the situation in terms of flood extent distribution—the head of the economic team had a statistical background that proved to be helpful—and its economic implications. Together they were able to frame the question about whether flood risk was included in land market prices in Newport Beach, an analysis that would not have been possibly done by the economic group alone. Collaboration with the social ecology team was not particularly fruitful. The attempt to add an economic question to the survey, for instance, did not succeed, the question being regarded as too technical to be integrated. What is more, the economic analysis that could be performed for the Tijuana site was neither really defined, nor sure to take place, notably because economic situations and data gathered or potentially available were really different between the two sites, thus questioning whether consistency could be respected.

Figure 3 highlights some features of the collaboration between the modeling, social ecology and economic teams, notably the intensity of interdisciplinary interactions. As shown, exchanges between teams have not been perfectly symmetrical, the modeling team having an overall bigger impact on research conducted.

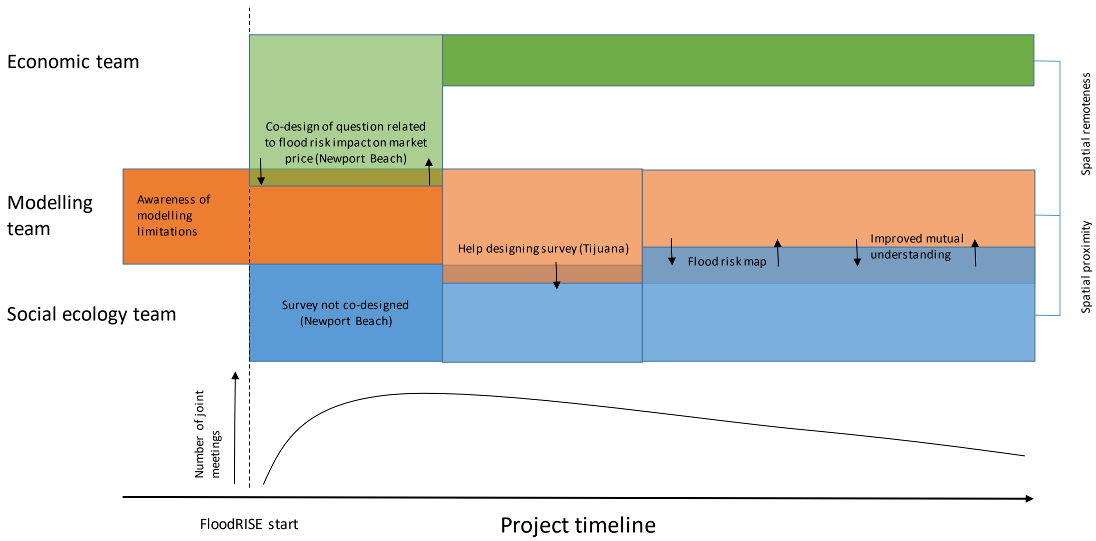

Figure 3. *Evolution of cross-disciplinary collaboration between three research teams.*

Discussion

Revisiting our initial question on the effect of limited planning and preparedness on the success of a cross-disciplinary project, we have observed how it was determined both by a certain level of path dependency, due to initial conditions, and by voluntarily measures implemented to counterbalance some of their negative impact. If neither the "mode" of interaction, nor the "logic" pursued (Barry and Born 2013) were explicitly defined beforehand, it seems that social sciences were "subordinated" to engineering sciences in order to promote more "accountability" on flood risk issues.

Heterogeneous Antecedents

Results have shown that researchers did not share a common understanding of concepts such as interdisciplinarity or transdisciplinarity, nor did they pursue similar objectives. This relatively low "level of readiness" (Stokols et al., 2003), understood as a researcher's capacity to efficiently collaborate at the beginning of an interdisciplinary project, among FloodRISE research teams was strongly influenced by the large number of disciplines involved, including a strong divide between social and engineering sciences. However, those initial intrapersonal barriers to interdisciplinarity were to a certain extent balanced by the spatial proximity of engineers and social ecologists at UCI and by the project management, led by a third party, institutionally independent from these two research teams. This early configuration seemed to correspond to a "subordination-service mode" or "vertical interdisciplinary cooperation" (Gethmann, Carrier et al. 2015: 79), in which the heterogeneity of scientific backgrounds and goals regarding the project tended to confer more importance on a discipline, namely engineering sciences.

Organic Process

The configuration of the project progressively changed during the survey process and became more horizontal, as common understanding and broad objectives were being increasingly shared among participants. Collaboration tended to develop pragmatically, according to an “instrumental interdisciplinarity” (Repko, 2014) aiming at solving a real-world problem: flood risk. On the one hand, this shift was made possible by the intensive dialogue-based method of collaboration that followed a learning curve. On the other hand, boundary researchers, who were graduate students, largely contributed to tighten communication between scientists and between scientists and local stakeholders. The willingness and capability to collaborate, even though they were not equally shared among researchers, certainly reflected the many soft skills they possessed: communication and problem-solving skills, creativity, teamwork capability, sociability and project management to name a few. If academic trainings insist on developing hard skills to acquire discipline expertise, cross-disciplinary research projects obviously require a good proportion of soft skills too.

The downside of this collaboration heavily relying on interpersonal relations was primarily its time-consuming aspect related to “linguistic and conceptual divides” (Eigenbrode et al., 2007) between engineers and social scientists. The pivotal role played by few boundary researchers/ graduate students also raises the question of whether their influence was meant to be so significant in the context of a project evolving organically. Regarding the interaction with local stakeholders, we may consider it as mostly instrumental, primarily serving an academic purpose, rather than a central objective aiming to produce policy recommendations in accordance with stakeholders’ needs.

Innovative Outcomes

The collaboration between the three research teams has produced significant outcomes so far, mostly related to the survey conducted in Newport Beach and in the Tijuana region. The added value of their inter- and transdisciplinary work lied in their capability to produce flood risk map integrating flood modeling and local stakeholders’ knowledge about their environment thanks to an innovative survey methodology allowing people to indicate their perception of flood risk on a tablet. This outcome would not have been made possible through a multi-disciplinary collaboration, since every phase of the research involved conceptual and methodological exchanges between at least two teams. Throughout this process, boundary researchers played both a quantitative and qualitative central role. They had indeed a higher frequency of interactions with other teams than regular researchers did, as well as the capability of dealing with multiple disciplines.

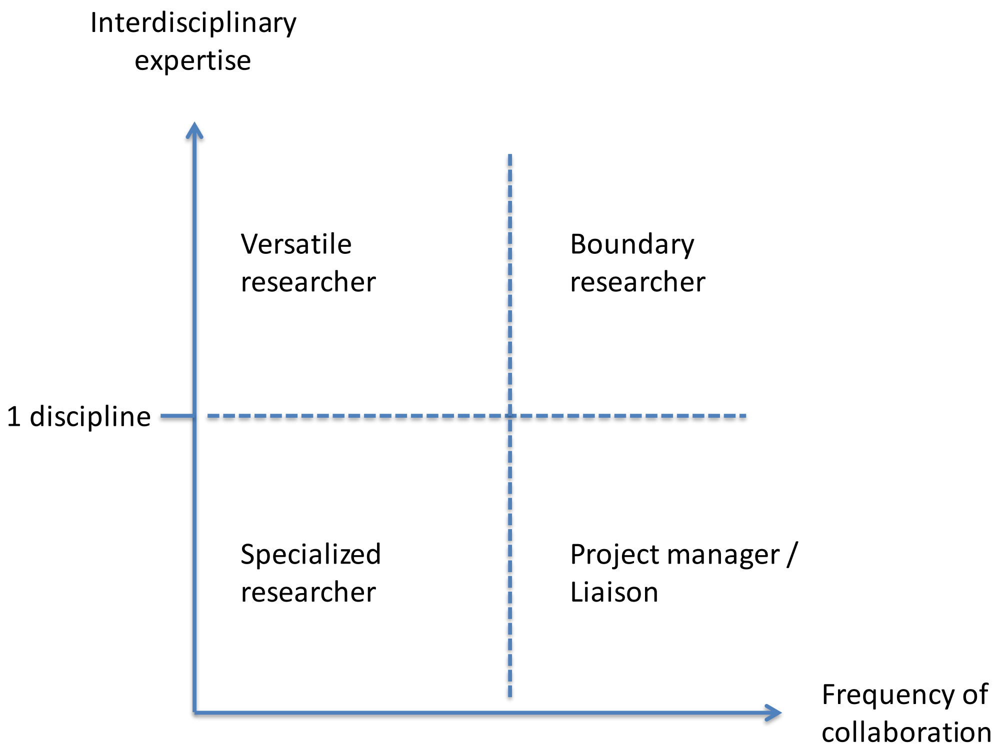

Figure 4. *Typology of researchers according to qualitative and quantitative features.*

As shown in Figure 4, we can consider four types of researchers, depending on the number of disciplines they master and on the frequency of their collaboration with researchers having different expertise. First, "specialized researchers" essentially work on their specific field of study without much interaction with other researchers. In the case of FloodRISE, engineers working on the general flood modeling illustrate this category. Second, "project managers" and "liaisons" bring different teams to work together, usually by facilitating communication and meetings between them. For instance, the FloodRISE project coordinator, and Newport site coordinator, played such a role. Third, "boundary researchers" are capable of bridging gaps between disciplines and of sustaining the emergence of a coproduced knowledge (Lawrence 2015, 2017). Typically, the postdoc in social ecology capable of efficiently dealing with engineers represented a good example of boundary researcher. Four, "versatile researchers" could potentially play the role of boundary researchers but have not the opportunity to do so and thus tend to work only within one of their discipline expertise. A good example of versatile researcher is given by a member of the social ecology team who had not the occasion to use her expertise in engineering despite her willingness to do so.

To sum up, the vast majority of researchers interviewed were specialized (around two thirds), while each other category had two representatives (approximately 10% each). Interestingly, this indicates that the success of FloodRISE relied on boundary researchers and project managers, whose influence was inversely proportional to their number.

Rationale for Interdisciplinarity

Regarding the organic development of the collaboration between the various teams, the interaction between social ecologists and economists highlighted some limitations to an unplanned interdisciplinary modus operandi, considering that the economic research group was demanding more collaboration. In fact, many positive outcomes of the project draw their origin from initial conditions such as the proximity between the main research teams on the UCI campus or the presence of boundary researchers. The eagerness of graduate students to play this role can be linked to impediments to interdisciplinary research, since "promotion criteria" are commonly cited as a major issue by researchers (National Academy of Sciences 2005: 76). In this context, graduate students might have been less sensitive than faculty members to the perception and valuation of their work by their home departments, in an academic system where disciplinary research is still the norm and where interdisciplinary outputs may be underappreciated (Evely et al., 2010).

FloodRISE researchers did not explicitly acknowledge many of the barriers commonly associated with cross-disciplinary studies: compartmentalization of universities, culturally diverse disciplines, reward mechanisms or publication issues (Boyd, Buizer et al. 2015). Neither did they intend to implement approaches to deal with those obstacles, for instance developing teaching tools, such as masterclasses on cross-disciplinarity practices (Lyall and Meagher 2012), or specific research skills to enable more efficient communication and system thinking. The whole research process clearly focused on mastering and integrating multiple disciplines insights and did not intend to reflect critically on knowledge production (Huutoniemi 2010; Repko 2014).

However, recognizing the inter- and transdisciplinary nature of the FloodRISE project, PIs decided to allow a large amount of time to foster communication between research teams, therefore triggering a process progressively overcoming an initial low level of preparedness.

Conclusion

What happens when cross-disciplinarity is emphasized as a core aspect of a research project but the heterogeneity of its team members is not formally handled in its early phase? In the case of the FloodRISE project, instead of producing a growing disconnect between research teams, the process followed has been capable of dealing with a low level of readiness by promoting an intense, time consuming, dialogue between researchers. What is more, boundary researchers played a crucial role in facilitating the transmission of information between research teams. However, the fact that none of these boundary researchers were faculty members questions the relevance of current reward systems in the academia. In terms of outcomes, the value added by the various cross-disciplinary collaborations was made explicit on several occasions, notably allowing the creation of innovative flood risk maps. Nevertheless, the difficulties faced by the research team located in San Diego to fully participate in the project is a reminder that shortcomings appearing during the design phase can not be easily overcome later on. In consequence, relying on an organic development and on boundary researchers cannot be considered as substitutes to a careful consideration of researchers' heterogeneity. A systematic assessment of the extent to which academic and social outcomes of cross-disciplinary research projects are affected by the presence of boundary researchers and the intensity of interaction between scientific teams should represent a promising direction for future research.

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