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Towards practitioner-initiated interactive knowledge development for sustainable development: A cross-case analysis of three coastal projects

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ABSTRACT

Although the central challenges of sustainable development are well-known, sustainability science has been slow in contributing to effective and feasible solutions for sustainable development. Turning knowledge into action for sustainable development therefore remains a major challenge for sustainability science. Interactive knowledge development is considered a prerequisite for sustainability-oriented action. Most studies approach interactive knowledge development from a researcher's perspective. This paper focuses on practitioners that initiate interactive knowledge development for sustainability-oriented actions. A cross-case analysis is presented for interactive knowledge development in coastal projects. Three cases are analysed through the framework of project arrangements and knowledge arrangements. The projects are located in the Wadden Sea, San Francisco Bay and the Ems estuary and address issues of flood control, nature restoration and liveability. The cross-case analysis revealed 11 causal mechanisms that help explain how project decision-making impacts on interactive knowledge development, how a process of interactive knowledge development functions and what its outcomes are. The mechanisms clarify the key underlying processes of interactive knowledge development in coastal projects. The mechanisms show that interactive knowledge development may result in sustainability-oriented solutions that are feasible for implementation. As such, this paper contributes to a practice-oriented understanding of turning knowledge into action for sustainable coastal development.

1. Introduction

Sustainability science seeks to facilitate a transition towards sustainability (Clark, 2007; Weinstein and Turner, 2012). In recent decades, the global agendas represent a converging view on the central challenges of sustainable development, namely: population, health, food security, biodiversity, energy, urban growth, water and sanitation, poverty, climate change, peace and security (Kates, 2012). Nevertheless, sustainability science has been slow in contributing to effective and feasible solutions for sustainable development (Kates, 2012; Van der Leeuw et al., 2012; Van Kerkhoff, 2013; Wiek et al., 2012a). Turning knowledge into action for sustainable development therefore remains a major challenge for sustainability science (Cornell et al., 2013; Kates, 2012; Van Kerkhoff and Lebel, 2006). Other components beyond knowledge may influence or constrain sustainability action, such as timing and legitimacy of policy-making processes (Polk, 2014) or dynamic complexity across different temporal and spatial scales (Sterman, 2012; Wu, 2013). Nonetheless, sustainability scientists agree that for sustainability-oriented action, knowledge should be interactively developed between researchers and practitioners (Cash et al., 2003; Funtowicz and Ravetz, 1993; Kates et al., 2001). This knowledge production, labelled in this paper as 'interactive knowledge development' is considered a prerequisite for sustainability-oriented action (Cornell et al., 2013; Kates, 2010; Lang et al., 2012; Van Kerkhoff and Lebel, 2006). This paper explores how interactive knowledge development functions when initiated by practitioners.

We use the term 'interactive knowledge development' to emphasise the interactive character of knowledge production while trying to avoid creating expectations regarding collaboration

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between researchers and practitioners. Concepts such as knowledge co-production (Clarke et al., 2013; Cornell et al., 2013; Lane et al., 2011) and joint knowledge production (Hegger et al., 2012; Van Buuren et al., 2004) emphasise the collaborative setting, ignoring the possibility that actors might be excluded or only partially involved during processes of knowledge production. Hence, the concept of interactive knowledge development does not specify types of involvement of researchers and practitioners. Such typologies on practitioner engagement in research are provided by (Krutli et al., 2010; Talwar et al., 2011; Van de Ven, 2007).

Although interactive knowledge development presumes interaction between researchers and practitioners, most empirical studies have approached this topic from a researcher's perspective by focusing on research programmes (Hegger and Dieperink, 2014) and transdisciplinary science projects (Polk, 2014; Lang et al., 2012; Wiek et al., 2012b). These studies provide insights on partnerships between researchers and practitioners, yet represent research processes that remain fairly detached from the societal arena where real-world problems are addressed. Whereas action-research studies are positioned in the societal arena, many empirical studies still discuss the process of knowledge production from an academic point of view (Johnsen and Normann, 2004; Wittmayer and Schäpke, 2014). Similarly, science-policy concepts as post-normal science and Mode 2 knowledge put researchers at the forefront of their diagnoses (Hessels and Van Lente, 2008; Kirchhoff et al., 2013; Turnpenny et al., 2011).

The limited attention for a practitioners perspective is problematic since various studies highlight how a weak link with on-going decision making and planning processes directly constrains the impact of knowledge for sustainability-oriented action (Blackstock and Carter, 2007; Polk, 2014; Wiek et al., 2012b). Furthermore, there are urgent calls in the sustainability sciences for researchers to engage with practitioners addressing real-world problems related to sustainable development (Clark and Dickson, 2003; Jäger et al., 2013; Kates, 2012). Therefore, the objective of this paper is to provide a more practical understanding on interactive knowledge development by focusing on practitioners that initiate interactive knowledge development for sustainability-oriented actions. Studies that approach the turning knowledge into action challenge from a more practical perspective focus on knowledge systems (Cash et al., 2003; Cornell et al., 2013), integration and implementation sciences (Bammer, 2013) and participatory management (Reed, 2008; Roux et al., 2006; Prell et al., 2007).

This paper focuses on coastal projects, more specifically how within coastal projects practitioners initiate interactive knowledge development for sustainable solutions. The term "practitioners" refers to a variety of actors: policy makers, regulators, project managers that are responsible for implementation of the project, and all other stakeholders with an interest in the knowledge production process. Besides a more practical understanding, this paper also responds to calls for comparative analyses on interactive knowledge development (Van Kerkhoff, 2013; Lang et al., 2012; Hegger et al., 2014) by presenting a cross-case analysis. Coastal projects offer a distinct domain for analysing interactive knowledge development since knowledge has to be developed for multimillion dollar solutions that are constructed for a lifespan of various decades (Seijger et al., 2014). Furthermore, coastal projects offer a direct opportunity to analyse how practitioners in the societal arena deal with place-based problems of sustainable development.

Around the world, projects show the difficulty of taking action that amounts to sustainable coastal development. For instance, controversies exist around land reclamation activities (Kim, 2012), dredging operations for expanding harbours (Korbee and Van Tatenhove, 2013) or traditional flood defence solutions (Temmerman et al., 2013). Since coastal problems evolve around conflicting interests and knowledge uncertainties, various researchers already promoted the involvement of both researchers and practitioners in knowledge production for coastal solutions (Clarke et al., 2013; Hanger et al., 2013; Schmidt et al., 2012; Tribbia and Moser, 2008). Within this paper, we consider a solution to be sustainability-oriented when human needs, economic objectives and environmental concerns are integrated within one solution.

In the three studied coastal projects, project managers have attempted to involve researchers, policymakers and stakeholders in producing knowledge for sustainable coastal solutions. The cases are located in the Netherlands (Wadden Sea and Ems estuary) and the USA (San Francisco Bay) and deal with issues of flood control, nature restoration and liveability. This cross-case analysis identifies the underlying mechanisms that explain the functioning of interactive knowledge development in the coastal projects. Case-specific findings have been published elsewhere (Seijger et al., 2013, 2014, in press). The remainder of this paper is organised in five sections. Section 2 explains the conceptual framework that is applied to the three projects. Section 3 outlines the method and procedures for data collection and analysis. Section 4 summarises the findings of the case studies and Section 5 discusses the cross-case analysis. Section 6 discusses the limitations and contributions of the understanding provided by the underlying mechanisms of interactive knowledge development for sustainability-oriented action.

2. Conceptual framework of project and knowledge arrangements

In analysing interactive knowledge development in coastal projects we have applied the framework of project arrangements and knowledge arrangements (Seijger et al., 2013, 2014). This framework builds on the policy arrangement approach (Arts et al., 2006; Van Tatenhove et al., 2000). A policy arrangement is defined as the temporary stabilisation of the content and organisation of a policy domain. Four dimensions make up the policy arrangement: actors and actor coalitions; the division of resources among actors; the rules of the game in operation; and the discourses of actors involved. These dimensions are interconnected and frequently illustrated in the form of a tetrahedron (Liefferink, 2006).

In order to study interactive knowledge development in coastal projects, Seijger et al. (2013, 2014) adapted the policy arrangement approach by dividing and extending it into a project arrangement and a knowledge arrangement (Fig. 1). The four dimensions of the policy arrangement apply to both the project arrangement and the knowledge arrangement, with the dimensions and indicators listed in Table 1. The project and knowledge arrangements differ in scope (see Fig. 1). The project arrangement represents the context of

Table 1
Dimensions and indicators for the project and knowledge arrangements.

Dimension	Indicator
Actors are defined as individuals or groups of individuals who are involved or affected by the arrangement.	Actor involvement; actors' relationships; actors affected; actor coalitions
Resources are defined as means available to an actor that can be used to influence or determine outcomes of an arrangement.	Time; money; information
Rules define the possibilities and constraints for actors to act within an arrangement. Both formal and informal rules may affect the actor constellation of an arrangement.	Access rules; allocation of responsibilities; legislation and policy; interaction rules
Discourses are defined as the interpretive framework or dominant interpretive scheme that give understanding and meaning to a particular arrangement.	Project rationale; project solutions; project scope

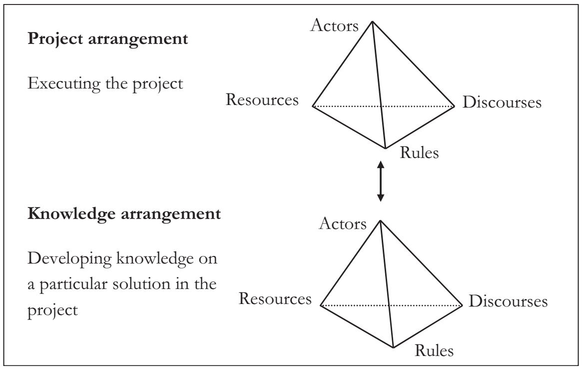

Fig. 1. Conceptual framework of project and knowledge arrangements.

application for which knowledge is developed. It focuses on the overall project goals and the activities undertaken to achieve them. For instance, the project arrangement explains how actors define problems, how they obtain funding (resources), and how project partners (actor coalitions) allocate responsibilities among them (rules).

The knowledge arrangement focuses on the knowledge production process for a particular solution in the project. The different scopes of a project and knowledge arrangement result in the involvement of other actors (like researchers or advocates of a particular solution), new resources in terms of funding and information, and, different legislation may be relevant to the particular solution when compared to the entire project. A knowledge arrangement is analysed through four activities (Van Buuren et al., 2004; Van de Ven, 2007):

- problem formulation – the scope of a problem is determined and research questions are formulated;
- selection of methods – discussions focus on the use of methods, techniques, models and theories for knowledge development;
- interpretation of results – results are interpreted, after which conclusions are drawn;
- choice of solution – a solution is chosen to address the problem under study.

The double-ended arrow in Fig. 1 emphasises the interconnectedness of the two arrangements.

In the project and knowledge arrangement framework used here, three aspects of interactive knowledge development are analysed: structuring factors impacting on interactive knowledge development (Manuel-Navarrete and Gallopín, 2012; Van Kerkhoff, 2013), dynamics during interactive knowledge development (Cornell et al., 2013; Edelenbos et al., 2011; Manuel-Navarrete and Gallopín, 2012; Van Kerkhoff, 2013), and consequences of interactive knowledge development for uptake in decision-making (Cash et al., 2003; McNie, 2007; Nowotny et al., 2001; Sarewitz and Pielke, 2007). Consequently, the framework enables an analysis into the causes and consequences of interactive knowledge development. A unique aspect of the framework is the dynamic analysis of these causes and consequences by applying the project and knowledge arrangement framework in a longitudinal case study. This dynamic analysis is essential to come to a better understanding of causes and consequences of interactive knowledge development, since it can provide an analysis of how the two are interrelated.

3. Method

3.1. Multiple case study

A multiple case study was undertaken to enrich and broaden the empirical understanding of interactive knowledge development in coastal projects. A case study approach makes it possible to identify and measure the indicators that best represent the theoretical concepts one wants to measure (George and Bennett, 2005). As such, case studies enable an in-depth analysis of complex, uncertain and multidimensional phenomena in their context (Flyvbjerg, 2006). Given the depth of the analysis, only a few cases can be studied but this results in a high internal validity (Flyvbjerg, 2006; Gerring, 2007). A cross-case comparison can deepen the understanding on the phenomena of interest (Miles and Huberman, 1994). In addition, the ability to generalise findings to a broader range of situations improves through appropriate case selection and case comparison (George and Bennett, 2005; Gerring, 2007; Miles and Huberman, 1994).

Three cases were selected: two coastal projects in the Netherlands (Wadden Sea and the Ems estuary) and one in the US (San Francisco Bay). These choices reflect a 'most different' research design (George and Bennett, 2005; Gerring, 2007; Landman, 2008) in that they share a number of key characteristics and a similar outcome, yet differ in terms of other possible explanatory factors. The shared characteristics of the selected cases reflect our research interest: coastal area projects that address local, place-based, problems. The selected projects are characterised by a diversity of actors involved in knowledge production, indicative of a process of interactive knowledge development. The cases differ in three aspects of project management, namely how they manage time, manage costs and project scope (Atkinson, 1999; Morris and Geraldi, 2011). A fourth defining aspect is the institutional context in which a project is embedded. The prevailing institutional structure both enables and constrains the practices of actors in projects (Grabher, 2002; Morris and Geraldi, 2011). Table 2 shows how the three cases differ in terms of these four aspects.

3.2. Data collection and data analysis

Each case was analysed longitudinally using the framework of project arrangements and knowledge arrangements. Data were collected from semi-structured interviews, project documents, observations of project meetings and field visits to project areas. Table 3 provides an overview of the data sources in each project.

The cross-case analytical procedure consisted of five steps. (1) The interviews were fully transcribed and qualitatively analysed using a template coding procedure (Crabtree and Miller, 1999; Miles and Huberman, 1994). Coding involves the labelling of text fragments, which was carried out in QSR NVivo. The template coding procedure consisted of three rounds. First, fragments were coded on the basis of indicators in the project and knowledge arrangements. Second, all the coded fragments were further categorised in order to enhance our understanding of the indicators. Third, links between the categories and indicators were explored by integrating the dimensions of the project arrangement and of the knowledge arrangement. This final third step provides the key findings for the project and knowledge arrangements based on the transcribed interviews. (2) To improve the internal validity of the analysis, findings were triangulated in two ways. Firstly, during the coding, findings were compared across interviews. Following this, the findings from the coding procedure were validated against project documents and observations of project meetings. (3) The coding and triangulation resulted in analyses of the project arrangement and knowledge arrangement. They discuss the actor dynamics in the arrangements in terms of actors, rules, resources and discourses.

(4) Case-specific causal mechanisms were developed from these project-knowledge arrangement analyses. Causal mechanisms specify the causal processes responsible for observed outcomes (Beach and Pedersen, 2013; George and Bennett,

Table 2
Similarities and differences identified in the most different research design.

	Wadden Sea: dike-reinforcement project	San Francisco Bay: nature restoration project	Ems estuary: spatial development project
Similarities			
Coastal zone	Dikes protecting Texel from the Wadden Sea.	Salt ponds between Silicon Valley and South San Francisco Bay.	Delfzijl's maritime zone adjacent to the Ems estuary.
Local place-based problem	17 km of dikes no longer meet safety norms.	The project owns 60.7 km^2 of salt ponds that could be restored.	The liveability of Delfzijl is seen as problematic, the project focuses on options in the maritime zone (35 km^2).
Interactive knowledge development actors	Government (regional and local), experts (mainly consultants), nature organisations.	Government (federal, state and local), experts (scientists and consultants), stakeholder forum.	Government (regional and local), experts (scientists and consultants), port authority, nature organisations.
Differences			
Scope	Provide flood control.	Restore tidal marsh.	Improve liveability.
Financial	Funding for project solutions is largely covered by a national programme.	Funding for project solutions is organised for each phase of implementation.	The project lacks funding to implement solutions.
Time	Considerable time pressures as original delivery deadlines were not met.	Little time pressure as final implementation phase should be completed by 2058.	No time pressure due to absence of funding for implementation.
Institutional context	The Netherlands.	California, USA.	The Netherlands.

Table 3
Overview of collected data in each case.

	Wadden Sea: dike-reinforcement project	San Francisco Bay: nature restoration project	Ems estuary: spatial development project
Period analysed	2005–2011	2003–2013	2009–2013
Interviews project arrangement	5	9	9
Interviews knowledge arrangement	5	10	6
Project meetings	2	6	4
Field trips	2	5	2
Project documents (number of files)	373	842	107

2005; Hedström and Ylikoski, 2010). Causal mechanisms, due to their structure, contribute to systematic understanding since they reveal how a set of causes contribute to interactive knowledge development outcomes. The mechanisms were derived and developed within the three individual case studies and they specify the functioning of interactive knowledge development. The mechanisms were developed by iterating between the case analysis, the conceptual framework and the drafted causal mechanisms. Elsewhere, we published two case studies and their associated case-specific mechanisms (Seijger et al., 2013, 2014).

The steps 1–4 were taken for each case study. This paper presents (5) the cross-case analysis that focuses on generic mechanisms that operate across the three cases. That analysis is informed by a variable-oriented strategy where variables are compared across cases (Miles and Huberman, 1994). The case-specific mechanisms serve as variables that are compared with each other to arrive at generic mechanisms. These generic mechanisms are developed iteratively by completing cross-case tables and re-examining the single case analyses. Through the cross-case analysis is the case-specific understandings of interactive knowledge development transformed to a systematic, generic, understanding.

4. Project and knowledge arrangements in individual projects

This section summarises the case-specific arrangements and causal mechanisms. The project arrangement summarises the decision-making process whereas the knowledge arrangement summarises how knowledge is developed for a particular solution. Elsewhere, we published the in-depth case analyses of the Wadden Sea dike reinforcement project (Seijger et al., 2014), the San Francisco Bay nature restoration project (Seijger et al., 2014) and the Ems estuary spatial development project (Seijger et al., in press).

4.1. Wadden Sea: dike-reinforcement project

4.1.1. Project arrangement

In 2005, 17 km of the 27 km of Wadden Sea dikes on the Dutch island of Texel failed to meet existing safety norms. The water board responsible for flood control initiated a dike-reinforcement project to ensure that the dikes would then meet the safety norms. Funding mainly came from the national flood risk protection programme. This programme determined the project discourse through their funding criteria: reinforcements should be sober, effective and robust. The water board collaborated with an engineering firm in following the environmental impact analysis procedure. The water board regularly met with the province and the municipality authorities due to their formal responsibilities. In 2009, the water board announced that they would investigate traditional, landward, alternatives to reinforcing the dikes.

4.1.2. Knowledge arrangement

A group of ten actors, all based on Texel, disagreed with the proposed landward alternatives. They called for research on alternative, more sustainable, solutions. One option would be a seaward solution entailing a sandy flood defence in the Wadden Sea, supplemented with salt marshes and oyster reefs. The water board refused to fund a study into this since such a solution would not meet the funding criteria of soberness and robustness. However, the municipality and a nature recovery programme decided to fund the study. An outline of a seaward solution was jointly developed and this served as a starting point for the study. The engineering firm and the water board interpreted the results and formulated the conclusions. Others were excluded from this process as the water board took full responsibility for the study. The nature recovery programme and the municipality (backed by an unpaid scientific advisor) heavily criticised the study and especially the cost estimates for a seaward solution. In response, the water board conducted a follow-up study in 2012 that indeed resulted in a more cost-effective design.

4.2. San Francisco Bay: nature restoration project

4.2.1. Project arrangement

In 2003, a restoration project acquired 60.7 km^2 of industrial salt ponds in the south of the bay. Since the 1850s, 83% of the South San Francisco Bay marshland has been lost and the project discourse was to restore and enhance wetlands in South San Francisco Bay while providing flood management and wildlife-oriented public access and recreation. The project management team (PMT) consisted of governmental and non-governmental organisations. The aim was that restorative actions should be completed by 2058. Given this time horizon, the PMT relied on researchers and adaptive management to adjust management decisions. The project discourse for Phase 2 planning (2010-onwards) was narrowed to tidal marsh restoration of the salt ponds. PMT members sought consensus among themselves prior to decision-making. Future funding was strongly linked to public support, and this was a key driver for collaboration with researchers and with governmental and non-governmental organisations.

4.2.2. Knowledge arrangement

Alternative restorative ideas for Phase 2 were developed in this arrangement. The alternatives included breaches in salt pond levees, ecotone transition areas, trails and viewing platforms. In 2010, the PMT identified ponds suitable for tidal marsh restoration. They presented their findings to the stakeholder forum, to researchers and to the regulators. In 2011, the PMT hired consultants to develop qualitative descriptions of the opportunities and constraints of the various alternatives. Their findings were reported in separate meetings to researchers, regulators and stakeholders. Based on the inputs from the researchers, the number of breaches was altered as well as the sizes and shapes of the proposed nesting islands. The regulators shared valuable permit-related knowledge in one-on-one meetings with the executive project manager. In February 2013, the PMT selected three alternatives for environmental impact analyses.

4.3. Ems estuary: spatial development project

4.3.1. Project arrangement

Delfzijl is a Dutch seaport, located on the banks of the Ems estuary. In 2009, the municipality initiated a spatial development project to improve the liveability of Delfzijl. This liveability was being threatened by a sharp population decline and the previous mono-functional planning. The project partners focused on solutions that would strengthen connections between the city centre, the harbour and the coastline. To implement such solutions, the municipality realised it would have to collaborate with the regional government and with non-governmental organisations. Despite this, as of 2011, the municipality had failed to reach a consensus on a proposed solution for flood control and tidal marshes. This resulted in a reorientation phase with the project partners realising that they lacked a shared problem analysis. The project partners regained a shared commitment through a spatial vision for the maritime zone. However, the project partners lacked funding for its implementation.

4.3.2. Knowledge arrangement

In 2012, the project partners decided to explore the feasibility of a seaward solution that had been outlined in the spatial vision. The solution combined expanding the city's beach with tidal marsh, recreation and flood control aspects. This study was conducted by a research consortium that was interested in 'building with nature' solutions in hydraulic engineering projects. The consortium and the project partners each funded 50% of the study. Their contrasting interests of generic building with nature research versus implementing an envisioned solution resulted in a six-month struggle over the research proposal. In November 2012, a coalition of nature organisations opposed the findings of the study on the basis that the proposed solution might hamper estuary restoration. The facilitator considered their criticisms leading to additional research. This additional research turned the nature coalition from opponents into advocates who then helped to develop a funding request for implementation. Due to the many meetings and additional research required one research organisation spent 40% more time than they had budgeted.

For each case, we developed causal mechanisms that could explain the interactive knowledge development. They reveal different interactive knowledge development processes (Table 4). These mechanisms have been positioned in the project and knowledge arrangements framework. This results in two types of mechanisms: ones that cross from the project arrangement to the knowledge arrangement; and mechanisms that operate within the knowledge arrangement.

5. Mechanisms in interactive knowledge development in coastal projects

5.1. Deriving generic mechanisms

The generic mechanisms that operate across the cases are developed iteratively, by comparing the case-specific mechanisms across the cases and re-examining the individual case analyses. Table 4 reveals four generic mechanisms that *affect* interactive knowledge development in the project arrangement. First (1): initiating actors are pressed to involve others in knowledge production (mechanisms 1a, 2a, 3a). Second (2): resources structure the knowledge arrangement and narrow the scope of what can and what cannot be investigated (mechanisms 1b, 2b, 3b). Third (3): actor relationships in the project arrangement affect the role of the main knowledge producer: either because the main knowledge producer is already a trusted partner (mechanism 1c), or because they are new to the project (mechanism 2c), or because they are an attractive partner in the sense they bring funding to the project (mechanism 3b).

Re-examining the data resulted in a fourth generic mechanism (4): sharing responsibilities supports interaction rules for interactive knowledge development. This mechanism was derived from the role of responsibilities (mechanism 1e) and interaction rules (mechanism 3d). In both the San Francisco Bay and the Ems estuary projects, actors shared decision-making responsibilities. This resulted in consensus-based interactions through which actors moved forward in small steps in the knowledge arrangement. In contrast, in the Wadden Sea project, a single actor was responsible and consequently less willing to involve other organisations. Other case-specific mechanisms in the project arrangement point to structuring impact of discourses (mechanisms 1d, 3c). As discussed in the second generic mechanism, this structuring impact on the scope of knowledge production occurs especially through resources.

In the knowledge arrangement, we could also identify four generic mechanisms that *explain*, or provide more detail, on interactive knowledge development. First (1): actors hold different perspectives on issues for which knowledge needs to be developed, and this results in differing contributions during interactive knowledge development (mechanisms 1f, 2d, 3e). Second (2): easily understood knowledge supports contributions by non-experts (mechanisms 1g, 2e, 3f). Third (3): facilitation smoothes

Table 4
Case-specific causal mechanisms for interactive knowledge development.

Orientation of causal mechanisms	Wadden Sea: dike-reinforcement project	San Francisco Bay: nature restoration project	Ems estuary: spatial development project
From project arrangement to knowledge arrangement	1a. The formal responsibilities of other actors were a key motive for involving them in the knowledge arrangement.	2a. The need for public support resulted in interactive knowledge being developed in the knowledge arrangement.	3a. Project partners realised they needed to collaborate over Delfzijl's maritime zone and this resulted in collaboration in the knowledge arrangement.
	1b. Time pressures in the project resulted in time pressures in the knowledge arrangement.	2b. Limited resources (information, time and money) narrowed the scope of the knowledge arrangement.	3b. Limited financial resources impacted on the actors and type of solutions in the knowledge arrangement.
	1c. The engineering firm became a trusted partner of the water board and they therefore conducted the study for a sandy seaward solution.	2c. The project memory of the actors structured the role of the consultancy team in the knowledge arrangement.	3c. The project discourse structured the problem-formulation knowledge arrangement.
	1d. Discourses in the project and in the knowledge arrangement determined the scope for knowledge development.		3d. The interaction rules of the project arrangement applied to the knowledge arrangement, ensuring that the knowledge arrangement was well embedded.
	1e. Legislation meant that the water board was responsible for the project and, therefore, they did not involve other actors in the interpretation of results and the formulation of conclusions.		
Within knowledge arrangement	1f. Involving a diversity of perspectives resulted in support from the actors involved.	2d. Including a diversity of perspectives broadened support among the actors involved.	3e. The interests of project partners, researchers and the nature coalition had to be bridged during the interactive knowledge development to achieve broadly accepted solutions.
	1g. Actors with limited technical knowledge found it difficult to comment on the study.	2e. The type of knowledge present (qualitative restoration alternatives) supported a process of interactive knowledge development.	3f. Easily understood knowledge facilitated understanding among participating actors.
	1h. The nature recovery programme facilitated interactive knowledge development through funding and conflict mediation.	2f. Professional facilitation smoothed the process of interactive knowledge development.	3g. Facilitation by the facilitator ensured a smooth process of interactive knowledge development.
		2g. A safe, confidential environment resulted in additional knowledge.	3h. One actor from the research consortium was excluded from this knowledge arrangement for budgetary reasons.
			3i. It was difficult to engage with the fragmented nature coalition.
			3j. The costs of interactive knowledge development were higher than expected.

the process of interactive knowledge development (mechanisms 1h, 2f, 3g). Further, mechanism 3h on exclusion appeared to represent another generic mechanism (4): actors were excluded in each case during one or more activities in the knowledge arrangement development. Other case-specific mechanisms in the knowledge arrangement point to barriers (mechanisms 3h, 3i), strategy (mechanism 2g) and the additional costs of interactive knowledge development (mechanism 3j).

The last group of generic mechanisms reflects the *consequences* of interactive knowledge development for actors in the projects. These were included in the case-specific mechanisms as broad support (mechanisms 1h, 2f, 3e) and high costs (mechanism 3j). Re-examining the data for outcomes related to interactive knowledge development resulted in three mechanisms. First (1): interactive knowledge development broadens societal support for solutions since involved organisations eventually support the developed solutions. Second (2): the proposed solutions become more feasible as actors make valuable contributions that change the design, reduce costs, or improve the permitability. Finally (3): significant time is consumed through this process due to all sorts of meetings being required plus additional follow-up research.

5.2. Key findings

Table 5 summarises the generic mechanisms identified. These mechanisms reveal how interactive knowledge development functions in the studied coastal projects. The mechanisms are positioned within the framework of project and knowledge arrangements. They cover three sorts of processes (affect, explain, consequences) as discussed in Table 5. These mechanisms were operating in all three cases (the empirical evidence is presented in Appendix I).

The mechanisms include three main findings. First, how a project is organised affects the process of interactive knowledge development. The practitioners tie the knowledge-production process to their local needs and interests. Project partners involve other actors since they have formal responsibilities that can hinder implementation of proposed solutions (Texel and Delfzijl project), or, because public support is linked to new tax measures and future funding for the project (San Francisco Bay project). The resources of key actors narrow the scope for knowledge production. In the Ems project, project partners had limited budget and therefore tried to exclude an industrial dumping site from the study since cleaning it up would be expensive. When responsibilities are shared between

Table 5
Identified generic mechanisms in interactive knowledge development in the studied coastal projects.

Type of causal mechanism	Description
From project arrangement to knowledge arrangement: mechanisms that *affect* interactive knowledge development.	Project partners are pressed to involve other actors in knowledge production. Project resources structure interactive knowledge development resulting in a narrowed scope for interactive knowledge development. Project-level actor relationships affect the actor that is the main knowledge producer. Sharing responsibilities at the project level supports interaction rules for interactive knowledge development.
Within knowledge arrangement: mechanisms that *explain*, or provide more detail on, interactive knowledge development.	Actors hold different perspectives, which results in differing contributions during the process of interactive knowledge development. Easily understood knowledge supports contributions by non-experts. Professional facilitation smoothes the process of interactive knowledge development. Actors are excluded during one or more interactive knowledge development activities.
From knowledge arrangement to project arrangement: mechanisms that specify the *consequences* of interactive knowledge development.	Support for solutions broadens through interactive knowledge development. Feasibility of solutions improves through interactive knowledge development. Interactive knowledge development consumes more time than expected.

project partners, a setting is created in which knowledge can be interactively developed. In San Francisco Bay the project partners followed a consensus-based approach that resulted in small, consensus-based steps in knowledge production.

Second, the differing perspectives of participating actors require a particular process for knowledge development. Facilitation is needed to ensure that differing contributions are heard and clarified. A nature recovery programme in Texel smoothed the process of interactive knowledge development by funding 90% of the study and by facilitating a discussion between project partners when outcomes of the study were disputed. Easily understood knowledge ensures that non-experts can also participate in interactive knowledge development. Examples range from maps of restoration alternatives in San Francisco Bay to a weblog and a qualitative assessment framework in the Delfzijl project. The partial exclusion of some actors is not fatal as long as they can voice their concerns and criticisms regarding the developed knowledge. For instance actors were initially excluded in both the Texel (municipality, nature recovery programme) and Delfzijl (nature coalition), yet their concerns and criticism were addressed in a later phase.

Lastly, it is vital to address such concerns and criticisms if one is to come to a shared understanding and solution that fits local conditions. Addressing concerns requires additional meetings and research. In San Francisco Bay it took three years to develop restoration alternatives, partly due to the many meetings with regulators, stakeholders and researchers. As a result, interactive knowledge development consumed substantial more time and budget than 'basic' research. In the Texel project, criticism from actors resulted in an unplanned follow-up study and in the Delfzijl project one research organisation spent 40% more time due to additional research. However, the additional time and budget may result in changes that improve the feasibility of the developed solutions and may also increase societal support since critical actors may come to accept the developed knowledge. The feasibility of the seaward solution in the Delfzijl project increased because researchers pressed to include the dumping site in the study since legislation would demand environmental compensation for the proposed solution. Societal support for restoration solutions in San Francisco Bay enlarged since concerns and potential drawbacks were detected and discussed during various meetings with stakeholders, researchers and regulators. This resulted in a shared understanding and support for the developed solutions.

6. Discussion

Given the importance of interactive knowledge development in turning knowledge into sustainability-oriented action (Cash et al., 2003; Cornell et al., 2013; Van Kerkhoff and Lebel, 2006), the objective of this paper was to provide a more practical understanding of interactive knowledge development by focusing on practitioners in coastal projects. In the introduction we stated that a solution is sustainability-oriented when human needs are integrated with environmental concerns and economic objectives. Although the studied solutions do not explicitly include economic objectives, they are considered to be economically feasible by the involved actors. In addition, each solution integrates human needs, in terms of flood control and public access, with environmental concerns linked to nature restoration. And although the solutions are not yet constructed, they are not rejected either. At present both the coastal solutions at Texel and Delfzijl are funded and the nature restoration solutions in San Francisco Bay are examined in an environmental impact analysis. Moreover, the mechanisms clarify how potential barriers to construction are lowered or removed since the three projects studied show how interactive knowledge development enhances societal support and the feasibility of the developed solutions. Consequently, the cases and identified mechanisms emphasise the significance of interactive knowledge development for informing sustainability-oriented actions. The upcoming years will tell whether the knowledge is in reality turned into action when the projects enter the construction phase.

This paper advances the understanding on how interactive knowledge development functions when initiated by practitioners, since a set of 11 mechanisms is presented that operates across three coastal projects. The mechanisms are directly linked to the process of knowledge production. The mechanisms offer a detailed explanation for the functioning of interactive knowledge development since they integrate three sorts of explanations: (1) how project decision-making impacts interactive knowledge development; (2) the actor dynamics that explain how differing contributions are aligned during a process of interactive knowledge development; (3) the outcomes of interactive knowledge development for decision-makers in the coastal project. Most of the individual mechanisms are in line with insights from other studies that focused on interactive knowledge development. For instance various authors already wrote that interactive knowledge development consumes additional time (McNie, 2007; Roux et al., 2006), or that knowledge should be made easily understandable to non-experts (Kirchhoff et al., 2013; Sheppard et al., 2011; Wiek et al., 2015) and that facilitators or knowledge integrators contribute to a smoother process in interactive knowledge development (Bammer, 2013; Cornell et al., 2013; Wiek et al., 2012b). Consequently, the set of mechanisms connect through a cross-case analysis different insights from literature, thus advancing the analysis of interactive knowledge development that is initiated by practitioners.

The question then is, what is the external validity of these mechanisms (George and Bennett, 2005; Gerring, 2007)? Given the setting in which they were identified, the mechanisms seem likely to apply to situations where practitioners initiate interactive knowledge development for sustainable, multifunctional coastal solutions. As such the mechanisms may be applicable to coastal zones where a high human dependency on the coastal space and resources puts pressure on coastal projects to combine various functions in sustainable solutions (Weinstein et al., 2007). Further research could provide greater insight into the range of institutional contexts where the mechanisms might apply. This paper has shown that the mechanisms could function in the institutional contexts of the Netherlands and the USA.

Whereas the above arguments specify and limit the main findings of the multiple case-study, this paper also contributes to a more practical understanding of interactive knowledge development for sustainability-oriented actions. Namely, (1) a conceptual framework that addresses the interplay between knowledge production and on-going decision-making; (2) a pragmatic motive to organise interactive knowledge development; (3) the role of power and exclusion in interactive knowledge development; and (4) the effectiveness of boundary spanning individuals in spanning boundaries between researchers, policy makers and stakeholders.

First, the conceptual framework of project and knowledge arrangements offers a relevant framework to analyse processes of knowledge production that take place in the societal arena, an arena where practitioners attempt to respond to real-world problems of sustainable development. The framework offers a detailed operationalisation of knowledge systems, since knowledge systems are institutional arrangements to link knowledge to action for sustainable development (Cash et al., 2003; Cornell et al., 2013). The project and knowledge arrangements draw attention to the interplay between interactive knowledge development and decision-making processes in terms of actors, rules, resources and prevailing discourses. Understanding this interplay is relevant as it is an often mentioned barrier for actionable knowledge (Blackstock and Carter, 2007; Polk, 2014). Existing frameworks fail to deliver these kinds of insights since they either focus on the institutional dimensions such as in knowledge governance (Van Kerkhoff, 2013) or, they do not separate the process of knowledge production from the institutional decision-making context where knowledge has to be turned into action (Edelenbos et al., 2011; Hegger et al., 2012).

Second, we saw that practitioners involved a diversity of actors in knowledge production, due to their goal of implementing coastal solutions,. This goal contrasts with theoretical arguments of incorporating knowledge that is widely distributed across society (Cornell et al., 2013; Gibbons et al., 1994; In 't Veld, 2010), or motives that address conflicting coastal interests and major knowledge uncertainties (Clarke et al., 2013; Hanger et al., 2013; Schmidt et al., 2012; Tribbia and Moser, 2008). Thus, this paper reveals that practitioners may have a different pragmatic motive to involve other actors in knowledge production, to avoid that they would later obstruct the implementation of solutions. An implication of this pragmatic motive is that practitioners might not take the extra effort to develop knowledge interactively when they expect no hindrances in the implementation phase.

Third, the cases show how power and exclusion are intrinsic to interactive knowledge development when initiated by practitioners in coastal projects. Flyvbjerg (1998) discusses how power defines what counts as knowledge and how knowledge results in power. Wiek et al. (2015) stress the importance of exploring and acknowledging power dynamics in participatory sustainability science projects. These kind of power perspectives are mostly absent for interactive knowledge development as authors conceive it as a collaborative endeavour between researchers and practitioners (Cornell et al., 2013; Hegger et al., 2012; Pohl et al., 2010). In this paper, the identified mechanisms reveal how power influences interactive knowledge development. A dependency on the resources of key actors structures what could be investigated. In addition, only a limited group of actors is involved. These are the policymakers who hold relevant formal responsibilities, other well-organised stakeholders who can attend the many meetings during the process of knowledge production and researchers who are hired to conduct research in relation to the project. These exclusions seen in practice contrast with arguments about involving the broadest possible coalition of actors and using collective problem framing (Cornell et al., 2013; Hegger et al., 2012; Lang et al., 2012; Roux et al., 2006). Consequently, aspects of power and exclusion require attention when analysing or designing processes of interactive knowledge development.

Fourth, in all the three projects studied, the boundaries between research and decision-making were spanned by individuals in their roles as project managers and facilitators. This contrasts with the literature that considers the use of boundary organisations as an effective approach for mediating between research and decision-making (Cash et al., 2003; Guston, 2001; Kirchhoff et al., 2013; McNie, 2007). Rather, this paper has shown that facilitation is also needed among policymakers and stakeholders to ensure that participating actors can contribute to, and support the developed knowledge. Consequently, key boundary spanning individuals might be better equipped for this task than boundary organisations, at least in the setting of coastal projects.

Based on this study, we propose further research that functions as opportunities for sustainability scientists to engage with practitioners in addressing real-world problems related to sustainable development. The project-knowledge framework could be extended with a normative component to evaluate the sustainability of the selected solution. For instance by using the sustainability assessment framework of Tainter (2003) by asking the questions: Sustain what? For whom? For how long? At what cost? The practice-oriented understanding of interactive knowledge development can be strengthened by testing the identified generic mechanisms in other coastal projects and in differing institutional contexts. In addition, the requirements and limits of interactive knowledge development could be further studied. How much more time and costs are consumed in meetings and additional research through developing knowledge interactively compared to 'basic' research? Are these investments repaid by an implementation of sustainability-oriented solutions, or does it merely result in muddling through? Lastly, the framework of project and knowledge arrangements could be used to explore how interactive knowledge development functions in other settings where sustainability-oriented actions are developed. For instance by analysing projects that are focused on local transitions to sustainability in areas such as water management, agriculture, energy and nature conservation.

To conclude, we started this paper by linking interactive knowledge development with turning knowledge into action for sustainable development. We supplement the researcher-oriented literature on interactive knowledge development by a more practical perspective. This perspective is based on practitioners in three coastal projects that initiated interactive knowledge development for sustainable coastal solutions. We derived eleven mechanisms that clarify the key underlying processes of interactive knowledge development in coastal projects. These mechanisms show that practitioners tie the knowledge production process to their local conditions and that they hire researchers to explore the feasibility of proposed solutions. The mechanisms discuss how interactions between researchers and practitioners may result in sustainability-oriented solutions that are feasible for implementation. Therefore, interactive knowledge development might offer a valuable approach for practitioners who seek sustainability-oriented solutions. Through this study, we hope to reshape current thinking on turning knowledge into action by encouraging research that focuses on and contributes to, practitioners addressing the day-to-day challenges of sustainable development.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.gloenvcha.2015.07.004.

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