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NARROWING THE GAP BETWEEN THEORY AND PRACTICE? INTERACTIVE KNOWLEDGE DEVELOPMENT IN A COASTAL DEFENSE PROJECT

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ABSTRACT

Coastal defence projects intend to develop solutions in a highly dynamic environment. The coastal zone is characterized by expanding cities, rising flood risks, economic activity, and a threatened natural environment. Developing relevant knowledge for solutions in coastal defence projects is therefore a challenge, which is further complicated by a gap between theory and practice. To narrow this gap, concepts such as Mode 2 knowledge and post-normal science are advocated both in literature and practice. However, little is known about those interactive forms of knowledge development, and they have been criticized for being both prescriptive and purely theoretical. Few studies offer empirical data about such interactive knowledge development, and even fewer present conceptual frameworks to actually analyze these forms of knowledge development. This paper presents an exploratory case study into interactive knowledge development in a project's context. The concepts of engaged scholarship and policy arrangements are adapted to study interactive knowledge development longitudinally in a coastal defence project. Within the Texel dike reinforcement project, interactive knowledge development is analyzed for a sandy seaward solution. Seven mechanisms were derived that affect a process of interactive knowledge development in the project. The mechanisms both underline the multifaceted character of interactive knowledge development, and support a better understanding of these complex processes in a project's context. How these mechanisms operate will be explained in this paper.

KEYWORDS: mode 2 knowledge, engaged scholarship, coastal defence, theory practice gap, planning

1. INTRODUCTION

In today's complex world large engineering projects require integrated solutions. This is especially clear for projects in the coastal area. They are carried out in a context of growing populations, changing climate, coastal erosion, increasing flood risks, economic activity, and a declining natural environment (Cicin-Sain and Knecht 1998; Kay and Alder 1999). Developing relevant knowledge for solutions in such a context seems a challenge and is further complicated by a gap between theory and practice. Developed knowledge is often not aligned with the demands of stakeholders, policy makers or (other) researchers. This can result in fierce opposition by stakeholders towards proposed solutions, a limited use of knowledge by policy makers, or "knowledge fights" between researchers. These consequences may delay a project, imply a waste of research money, and solutions that do not meet the requirements of stakeholders. This paper focuses on the field of coastal defence, as research in this field is often

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not considered relevant in the decision making process by policymakers (van Koningsveld 2003; Merkx and Besselaar 2008; Tribbia and Moser 2008).

The gap between theory and practice refers to the limited use of research and is part of a larger debate in literature and practice. Van de Ven and Johnson (2006) distinguish three ways in which the gap between theory and practice may be addressed: as a knowledge transfer problem, as a misunderstanding of the relationship between scientific and practical knowledge, and as a knowledge production problem (Etzkowitz and Leydesdorff 2000; Gibbons 2000; Nowotny, Scott et al. 2001; van de Ven and Johnson 2006). There is a growing recognition that the theory-practice gap may be a knowledge production problem. Many concepts have been developed over time to narrow the gap between theory and practice by advocating interactivee forms of knowledge development: examples are Mode 2 knowledge (Gibbons, Limoges et al. 1994), post-normal science (Funtowicz and Ravetz 1993), civic science (Lee 1993), triple helix (Etzkowitz and Leydesdorff 2000), and engaged scholarship (van de Ven 2007). Such concepts refer to multidisciplinary research and engagement with people outside the research community. In coastal defence projects this would refer to the involvement of stakeholders, policymakers and different researchers in knowledge development.

This paper contributes in two ways to the body of knowledge of engineering project organisations. First, it presents a thorough methodology for analyzing interactive knowledge development in a project's context. This is a first important step into analysing interactive knowledge development in practice. Especially as there is, for as far as we know, only one conceptual framework published that supports an analysis into interactive knowledge development in a project's context (Hegger, Lamers et al. 2012). Second, this paper improves our empirical understanding of interactive knowledge development. This empirical foundation is necessary, as several authors have criticized concepts as Mode 2 knowledge for being prescriptive and purely theoretical (Weingart 1997; Godin 1998; Shinn 2002). The case study reported in this paper illustrates how interactive knowledge development is organised in an engineering project: the Texel dike reinforcement project. The paper will discuss seven mechanisms that are involved in interactive knowledge development for a sandy seaward solution during the planning phase of this project.

In the next section we discuss the conceptual framework and methodology for analyzing interactive knowledge development in a project's environment. Section three presents the results of applying this methodology to the Texel dike reinforcement project. Finally, section four discusses our main conclusions and points for discussion.

2. METHODS

This section discusses our research approach. A case study approach is adopted to enable an in-depth and longitudinal analysis of knowledge development in a specific coastal defence project. So far we have used the generic term of *interactive knowledge development* to refer to a process of knowledge development that involves a diverse set of actors. From now on, we replace this generic term by a more specific one: *engaged knowledge development.* Our conceptual framework enables an analysis into engaged knowledge development by focusing on project and knowledge arrangements. Data triangulation is done by validating our main findings from interviews with other sources such as project documents. The qualitative analysis is structured by a coding procedure using qualitative data analysis software (QSR Nvivo 9).

2.1 Conceptual framework

Engaged knowledge development

We define engaged knowledge development as a participative form of knowledge development in which knowledge is shared and developed by obtaining perspectives of key stakeholders involved in the complex problems that are being studied. We adopted this concept from engaged scholarship (van de Ven 2007) as it specifies different phases in a research process, already acknowledges the existence of different forms of engaged scholarship, and it enables an analysis into the involvement of researchers, policymakers and stakeholders in knowledge development.

Knowledge as a concept is frequently described as fuzzy, complex, contextual and multifaceted. Not surprisingly, many definitions exist on what knowledge is. Authors reflect differing dimensions as experience and information, human action, or different types of knowledge (Bläckler 1995; Nonaka and Takeuchi 1995; Davenport and Prusak 1998; Weggeman 1999; Florijn, Gurchom et al. 2000). We consider knowledge development to be an interactive process between actors through which tacit and explicit knowledge are transformed into (new) explicit knowledge. Both tacit and explicit knowledge highlight separate aspects of knowledge (Tsoukas 1996). Tacit knowledge is captured in Polanyi's description "we can know more than we can tell" (Polanyi 1966). It is knowledge that is situated in someone's actions, procedures, routines, ideals, values and emotions (Nonaka, Toyama et al. 2000). In comparison, explicit knowledge is more tangible, and can be transformed, processed, and retrieved easily (idem). We refrain from adopting other typologies or dimensions of knowledge as we have positioned ourselves already in the on-going debate of more interactive knowledge development, acknowledging the importance of context and multiple perspectives by focusing on engaged knowledge development: a type of knowledge that is developed by obtaining multiple perspectives of actors involved in the complex problem being studied.

Various authors highlight the need for empirical research into new forms of knowledge development[5] (Weingart 1997; Tuunainen 2002; Hegger, Lamers et al. 2012). Only recently a framework for joint knowledge development in projects is presented by (Hegger, Lamers et al. 2012). They conceive projects as policy arrangements, aiming to analyse the degree of success for joint knowledge development. Their framework does not operationalise a process of knowledge development, and therefore knowledge production remains somehow a black box. We argue that engaged knowledge development in a project's context requires further operationalisation, to be able to study this complex and fuzzy concept. To do so, we build upon the framework of (Hegger et al. 2012).

Project arrangements

Project arrangements are used to study the project in which knowledge is developed. Project arrangements capture the content and organization of a project. The concept is derived from the policy arrangements approach (van Tatenhove, Arts et al. 2000). We adopt this approach for several reasons as it can be applied to knowledge development in a projects' context. The policy arrangements approach is grounded in Giddens notion of duality of structure. The duality of structure acknowledges that actors affect structure through their practices, and that

[5] Also van de Ven acknowledges the lack of empirical evidence for his model of engaged scholarship in his final chapter, as *"the proof is in the pudding"* and *"time will tell"* whether his model results in more penetrating and relevant research (van de Ven, 2007: pp. 296-297)

structure affects the practices of actors (Giddens 1984). In other words, it stresses the importance of actors who act in a context. Actors affect the context, and the context affects the possibilities for acting. Similar to policy domains, projects have a temporary character and are dynamic over time (Turner and Müller 2003). These aspects are explicitly addressed in the policy arrangements approach, as changes in one dimension may invoke changes in other dimensions and policy arrangements are defined as temporary (Arts, Leroy et al. 2006). An arrangement consists of four dimensions: actors, resources, rules of the game, and discourses (van Tatenhove, Arts et al. 2000) .

To do justice to the different levels of analysis we transform the concept of policy arrangements into project arrangements. The dimensions of a project arrangement are:

1. Actors and their coalitions involved;
2. The division of resources between actors that lead to differences in power and influence;
3. The rules of the game in operation, both in formal procedures and informal routines of interaction;
4. Discourses, that entail views and narratives of actors involved. Discourses can structure behaviour of actors, and actors can bring new discourses into the domain thereby affecting the structure.

These dimensions are strongly interconnected and changes in one dimension might cause changes in other dimensions. An arrangement is therefore conceptualized as a tetrahedron, in which each of the corner represents one dimension (Liefferink 2006) (see also figure 1).

Knowledge arrangements

To be able to analyse interactions around knowledge development within the context of a project, we introduce the term knowledge arrangements. Whereas project arrangements focus on the organization and content of a project, knowledge arrangements capture the organization and substance of knowledge development in a project. By separating project from knowledge arrangements we can not only analyse dynamics within an arrangement, but also study the influence of both arrangements upon each other. This is important, as developments at a project level are likely to influence knowledge development (and vice versa).

In order to study processes of engaged knowledge development we conceptualise a process of knowledge development. By distinguishing different activities we can specify per activity the level of engagement between actors. Knowledge development is conceptualised as a process of four main activities after (van Buuren, Edelenbos et al. 2004; van de Ven 2007). The activities are highly interrelated, and within a knowledge arrangement iterations between activities can occur. The activities are:

1. Problem formulation – In this activity the scope of a problem is determined, and discussions focus on 'what the actual problem is'. Research questions are formulated whereupon data will be collected.
2. Methods and techniques to be used – The methodology of data collection is subject of the second activity. Choices have to be made regarding the usage of methods, techniques, models, and theories.
3. Interpretation of results – Once data has been collected results have to be interpreted. What are the main findings? Accordingly, conclusions should be formulated.
4. Choice of solution - The fourth activity focuses on the choice of a solution. How are we going to solve the problem under study?

Figure 1 presents our conceptual framework that enables an analysis into processes of engaged knowledge development in a projects' environment. The dimensions are operationalized through different indicators, which are discussed in Annex 1.

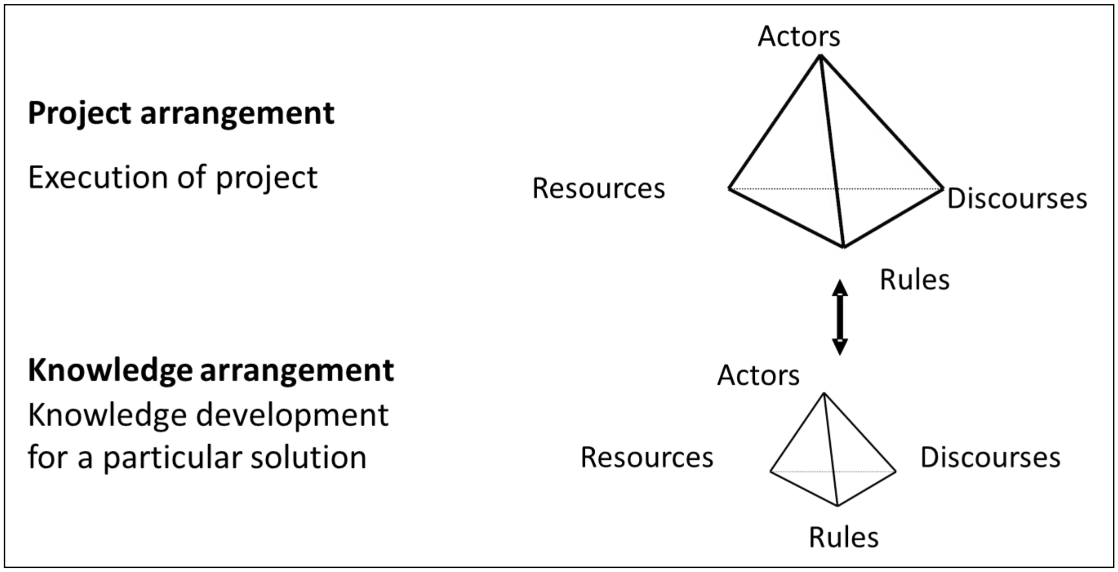

Figure 1. Conceptual framework for analysing engaged knowledge development in a project.

2.2 Case study approach

The case study method is used to study processes of engaged knowledge development in coastal defence projects in-depth. (Gerring 2004) identifies the case study as an intensive study of a single unit for the purpose of understanding a larger class of (similar) units. (Yin 2003) highlights the importance of contextual factors stressing that in case study research phenomena are analyzed in their context in which boundaries between phenomena and context are not always clearly evident.

Since this study is exploratory by nature, a case study offers us the opportunity to study knowledge development longitudinally and to observe changes over time. Furthermore, case studies have a high construct validity as they can collect empirical information that accurately captures the concepts in the theoretical model (Mitchell and Bernauer 2004). This high construct validity is important because phenomena as engaged knowledge development and policy arrangements are too complex and interwoven to be operationalized by numeral variables. At last, case studies can identify causal mechanisms and determine scope conditions under which causal mechanisms have an effect (Bennet 2004; Gerring 2004; George and Bennet 2005). Causal mechanisms link causes to effects[6]. We focus on causal mechanisms that affect processes of engaged knowledge development.

[6] Causal mechanisms are defined as *"Ultimately unobservable physical, social, or psychological processes through which agents with causal capacities operate, but only in specific contexts or conditions, to transfer energy, information, or matter to other entities. In so doing, the causal agent changes the affected entity's characteristics, capacities, or propensities in ways that persist until subsequent causal mechanisms act upon it"* (George and Bennet 2005:137)

We developed a conceptual framework to study processes of engaged knowledge development. The framework is developed prior to data collection and therefore structures it. However, data collection and analysis ensured a semi-open procedure towards the collected data as discussed in section 2.3.

The Texel dike reinforcement project was selected because knowledge development plays an important role in this case, and demands between various actors were clearly not aligned. The project is part of an Environmental Impact Assessment procedure. This procedure requires research into different alternatives for dike reinforcement. Consequently, knowledge is developed for different solutions that can reinforce the dike. A group of actors challenged the solutions for which initially knowledge was developed, and initiated knowledge development for an alternative solution: a sandy seaward solution. Various actors are involved in the different activities of engaged knowledge development for this solution. This makes this project and particular solution worthwhile to study, as it represents a process of engaged knowledge development within a project's context.

2.3 Data collection and analysis

Three type of data sources are used in this research: qualitative interviews, participant observations, and secondary data analysis. Data was collected to describe the project arrangement (2005 to present), and knowledge development in the knowledge arrangement of a sandy seaward solution is covered over the period 2010-2011.

Interviews were held to explore the views of key actors involved in the dike reinforcement project. The interviews offered us insights into the actor's views of on-going dynamics in the project and knowledge arrangement. Ten interviews were held, five focused on the project arrangement and five on the knowledge arrangement (see Annex 2 for the list of interviewees). Interviewees were sent a topic list in advance that listed the subjects of either a project or knowledge arrangement. The interviews were semi-structured as an interview guide was used to ensure that different indicators of our conceptual framework were covered in each interview. Annex one specifies the topics that were addressed in each interview. Interviewees approved the audio recording and a summary of the conducted interview was send to interviewees for validation.

Interviews were fully transcribed and coded using QSR NVivo. Coding is a process of naming fragments by giving them a summarizing label (Boeije 2010). Through coding we could analyse the different dimensions in our framework, and the interactions between the project and knowledge arrangement. Our coding approach is based upon three rounds of coding: deductive, axial and selective coding.

Indicators of the various dimensions from our conceptual framework (Annex 1) formed the codes for the deductive coding round. Axial coding refers to a process in which fragments of the first round are categorized (Boeije 2010), this enhanced our understanding of the indicators in our framework. For example, fragments of actor relations could be axially coded into character, motive, role, and level of a relation. Selective coding refers to a process of looking for connections between categories (Boeije 2010). Through selective coding we integrated the different dimensions of our framework and derived our key findings as discussed in the next section. Output of the coding was discussed in different meetings within our research group and validated with other data sources.

Participant observations in two meetings offered us the opportunity to directly observe interaction processes between actors in the project and knowledge arrangement. In a public information meeting alternatives for dike reinforcement were presented to the public on Texel in October 2011. In a closed meeting in December 2011 actors discussed optimisation possibilities for one specific alternative. The observations helped us to put the interviews into perspective.

Access to more than 300 project documents was granted by the regional water board Hoogheemraadschap Hollands Noorderkwartier (HHNK). We categorized the project documents to facilitate easy retrieval. Among the project documents were reports, meeting notes, presentations, and letters. Two lists of critical events for the project and knowledge arrangement were composed on the basis of these project documents. Both lists were validated with several respondents. In addition, project documents were used to triangulate findings from interviews and observations.

3. THE TEXEL DIKE REINFORCEMENT PROJECT

The island of Texel is located in the Dutch part of the Wadden Sea (see figure 2). The Wadden Sea is a fascinating intertidal coastal system, characterized by barrier islands, tidal flats and estuaries. The coast stretches from Den Helder in the Netherlands along the north of Germany to Esbjerg in Denmark. Because of the unique geomorphology and biodiversity, the Dutch and German parts were designated as UNESCO World Heritage Site in June 2009. Important functions in the Wadden Sea area are recreation and tourism, industry, economy, nature and coastal defence (Reise, Baptist et al. 2010). The function of coastal defence affects many people, as in the Dutch flood prone areas more than 1.2 million people are located. New modes of knowledge development, as described in previous sections of this paper, are actively advocated in the area by different organisations[7].

Figure 2. The Wadden Sea in the Netherlands, of which Texel is the most westerly island.

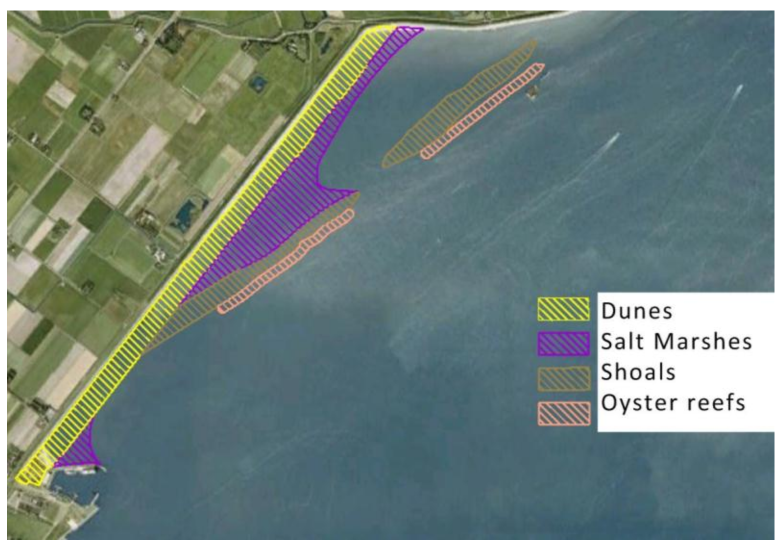

Figure 3. Visualisation of the sandy seaward solution at Texel, the solution covers a length of 3.2 kilometers (Source: Oplegnotitie Startnotitie, 2011)

[7] The Wadden Academy focuses on co-creation of knowledge, the Delta Programme adopts a joint fact finding approach, and Nature Recovery Programme Towards a Rich Wadden Sea advocates their learning by doing approach.

In this section, the results are presented of our analysis of knowledge development within the Texel dike reinforcement project. This project is part of an Environmental Impact Assessment procedure (EIA). This procedure requires research into different alternatives for dike reinforcement. Consequently, knowledge is developed for different solutions that can reinforce the dike. We analyzed knowledge development for a sandy seaward solution (see figure 3), an alternative that needed additional research for which a variety of organizations is involved. The arrangements are presented as coherent descriptions, without discussing each dimension separately. The latter is briefly done in Annex 3.

3.1 Project arrangement

Primary flood defences in the Netherlands are tested every five years in a safety assessment against the latest safety norms. Flood defences on the island of Texel have a safety norm of 1/4.000. In 2005, 17 out of 27 kilometers of the Wadden Sea dike on the island of Texel failed to meet these safety norms. Following this, the regional water board Hoogheemraadschap Hollands Noorderkwartier (HHNK) initiated a dike reinforcement project to ensure that the dike on Texel will meet the safety norms again. This is part of an Environmental Impact Assessment Procedure. In June 2009, a Notification of Intent was published by HHNK in which different alternatives for each dike section were presented. The water board expects to present a concept dike reinforcement plan in 2013.

Five national acts apply to the dike reinforcement project and allocate various responsibilities to different actors. First, the Water Act describes the prevailing safety norms and assessment framework for primary flood defences. This act makes HHNK responsible for the safety of their flood defences, appoints the Flood Risk Protection Programme (HWBP) as subsidizing body, and the province as supervisory body over the water board. Second, in the Nature Protection Act is the protection of nature in Natura 2000[8] areas organized. The Wadden Sea near Texel is declared as Natura 2000 area. The Province of Noord-Holland is responsible for Natura 2000 permits. Third, The Environmental Management Act discusses the organization of an Environmental Impact Assessment procedure. Fourth, the National Water Management Agreement discusses financial arrangements for dike reinforcement projects between the regional water boards and the Dutch government. Fifth, the spatial planning act states that the municipality is responsible for the zoning scheme. This is relevant as various alternatives for dike reinforcement require changes in the zoning plan. The act also states that the municipality can be overruled by the Province.

To arrange the involvement of several organizations the water board created three groups in the project: a core group, a project group, and an advisory group. HHNK and Witteveen+Bos form the *core group*. HHNK is initiator of the dike reinforcement project, and has the responsibility to ensure that the Wadden Sea dike meets the safety norms. Witteveen+Bos is an engineering and consultancy company and assists HHNK in the different steps of the EIA procedure and conducts most of the research into different alternatives for dike reinforcement. Purpose of the core group is to coordinate and execute the project. The *project group* consists of the core group, Province of Noord-Holland, and the Municipality of Texel. Those actors

[8] Natura 2000 is the central feature of the European Union's nature and biodiversity policy. It is an EUwide network of nature protection areas established under the 1992 Habitats Directive. The aim of the network is to assure the long-term survival of Europe's most valuable and threatened species and habitats.

participate in the project group as they have various legal responsibilities. Responsibilities between actors are also allocated in administrative meetings with administrators from the province, water board and municipality. In the *advisory group* are actors involved who are somehow affected by the dike reinforcement project, for example farmers, inhabitants and nature organizations.

Funding for the dike reinforcement project comes mainly from the Flood Risk Protection Programme (HWBP). Their funding criteria for reinforcement are soberness, effectiveness, and robustness. These funding criteria are a dominant discourse that structures the possible solutions for reinforcement as highlighted in the following quote: *"HWBP told us (…) we finance a sober and effective solution, we do not subsidize additional spatial quality"* (HHNK, 15-12-2011). Reports are send every three months from HHNK to HWBP, discussing progress, risks, and planning.

The project has grown considerable in costs and original delivery deadlines have not been met. The original delivery deadline of 2015 is postponed to 2019. Expected costs have risen over the years to 200 million euros. New insights enlarge the scope and impact of studied alternatives, and therefore delay the dike reinforcement and make it more expensive. Respondents mention three causes for the changing scope and impact: uncertainties in proper boundary conditions, new piping calculations, and a switch to an integral reinforcement strategy. As HWBP (including the project at Texel) has grown considerably in costs, a report is required every six months by the House of Representatives on expected costs and progress made.

In short, HHNK is responsible for the dike reinforcement project. They cooperate closely with Witteveen+Bos and involve a range of actors in the project. The arrangement is strongly grounded in legislation, which determines to a large extent the involvement of other actors. Pressing resources as time and money put the project under strict supervision by HWBP and the House of Representatives. The funding criteria of soberness, effectiveness and robustness are a dominant discourse that structures the possible solutions for reinforcement.

Projects which are part of HWBP do not directly strive for a process of engaged knowledge development. Respondents confirm that there is no explicit ambition around engaged knowledge development in the dike reinforcement project. In stead, the main project goal is to ensure water safety within boundary conditions of time and money. Nonetheless, initiatives for solutions have been launched by various actors that at first sight do not meet the funding criteria, and that represent a process of engaged knowledge development. We will focus on engaged knowledge development for one such solution: a sandy seaward solution.

3.2 Knowledge arrangement sandy seaward solution

We observe three knowledge arrangements that focus on solutions for dike reinforcement at Texel[9], having a different scope and involving other actors. First, landward solutions are developed in the *core group*. These solutions are based upon standard engineering solutions for the various failure mechanisms of a primary flood defence (i.e. flooding, piping, stability). Second, knowledge is developed for innovative solutions (soil improvement and geotextile) that can cope with piping and occupy less space than traditional solutions. Knowledge is developed by a group of actors: Witteveen+Bos, HHNK and other water boards. Third, knowledge is

[9] National research programs such as Strengths and Loading of Flood Defences (SBW) are beyond the scope of this paper. In the SBW program knowledge is developed to improve the safety assessment framework for flood defences, for example by improving piping calculations and hydraulic boundary conditions.

developed for a sandy seaward solution in front of the Prins Hendrikpolder involving a diverse group of actors. We will now turn to knowledge development in this arrangement.

Initial ideas for a sandy seaward solution were formed during meetings that focused on sustainable transitions for Texel organized by a national sustainability platform in the period 2007-2009. Actors as the deputy director of NIOZ (Netherlands Institute for Sea Research) and the Municipality of Texel drew the link with the dike reinforcement project, and started to think about sustainable seaward alternatives.

In response to the Notification of Intent, a group of actors requested the investigation of alternative solutions in September 2009. One solution mentioned is a sandy seaward solution for the sea dike bordering the Prins Hendrikpolder. The written response was signed by a group of ten actors. Among them are the Municipality of Texel, NIOZ, three village committees, and two nature organizations. In a government meeting in October 2010 HHNK, municipality of Texel and the Province of Noord-Holland decide to include a sandy seaward solution as one of the alternatives in the Environmental Impact Assessment procedure.

Knowledge is developed on the financial, technical, and legal feasibility of a sandy seaward solution. Nature Recovery Programme Towards a Rich Wadden Sea (PRW) is an important financer of research into the technical and legal feasibility of a sandy seaward solution. Such a solution links closely with PRW's ambitions to soften the borders between land and sea in the Wadden Sea. We will now discuss knowledge development for the technical study of a sandy seaward solution.

Knowledge development in technical study sandy seaward solution

The four different activities of knowledge development, as defined earlier in this paper, are applied to the technical study. The study focused on the technical design and expected costs for construction and maintenance of a sandy seaward solution. The study started in December 2010 and was finished in September 2011. PRW financed 90 % of the study and the Municipality of Texel 10%. Witteveen+Bos conducted this study, and hired Deltares, Arcadis, and Kees Vertegaal Ecologisch Advies for smaller parts of the study. The assignment for Witteveen+Bos was formulated in mutual agreement by HHNK, Municipality of Texel and PRW. HHNK would remain supervisor of Witteveen+Bos.

The Municipality of Texel and the NIOZ deputy director organised an expert meeting to develop a feasible design of a sandy seaward solution with respect to Natura 2000 legislation. Various actors jointly developed a sketch plan for a sandy seaward solution. Because the sketch plan received support of all the actors involved, it was used as point of departure for the technical study by HHNK and Witteveen+Bos. Research questions were initially formulated by Witteveen+Bos, and then presented for agreement to HHNK, Municipality of Texel and PRW.

Time pressure of the project arrangement affects the technical study as the following quote demonstrates: "*The study is conducted under severe time pressure. A sandy seaward solution may not distort the planning of the overall dike reinforcement project, this planning is already under pressure*" (Witteveen+Bos, 20-01-2012)

In June 2011, a technical meeting took place in which Witteveen+Bos, the NIOZ deputy director, Municipality of Texel, and the Arcadis expert participated. The technical approach and initial results were discussed. Another point of discussion was the question whether there is net erosion or sedimentation in the proposed area of the seaward solution. Models predicted net erosion, whereas the NIOZ deputy director observes in practice sedimentation in the area. These discussions resulted in the incorporation of a qualitative historical analysis, and the input of additional monitoring data into the quantitative models. Other methods used in the technical study are the sketch plan as point of departure, a qualitative description of the morphological system, and quantitative models for wave conditions, sediment transport and erosion.

The results have been interpreted by Witteveen+Bos and HHNK. An expert of Arcadis reviewed the full report. Perspectives differ upon the input of other actors as the Municipality, PRW and the NIOZ deputy director. *"We discussed draft versions with them* (red. Municipality, PRW, province). *Final versions have been discussed extensively, and we discussed it in the project group"* (HHNK, 24-01-2012). Whereas other quotes show a different perspective: *"I have no clue who saw the results of the studies. We gave the assignment, which was conducted in three quarters of a year. By then, we received the final draft, on which we could respond with some last comments"* (PRW, 14-12-2011) *"If they would have contacted the Municipality of Texel (…) They were not involved in-between, how steps have been elaborated and what the costs would be. The outcomes were suddenly presented, and that was it.* (NIOZ deputy director, 20-02-2012)

Both respondents of the province and the municipality mention the limited time they got for commenting the report. Conclusions have been formulated by HHNK and Witteveen+Bos, and were presented in the project group. This is explained by one respondent as follows. *"PRW, The municipality and other parties consider the report as a product of the water board (…) it is our report. Therefore we have to support it 100% before we send it to others* (HHNK, 24-01-2012)

As the sandy seaward solution is one of the alternatives being studied in the Environmental Impact Assessment procedure a solution for the Prins Hendrikpolder was not chosen after the technical study was finished. Various actors questioned the final design and estimated costs of 90 million euros for a sandy seaward solution in the technical study, as the following quote illustrates *" I am really disappointed by the lack of a search for a cheaper design. Everybody knew that the costs would be a decisive factor. I find it disappointing"* (Municipality of Texel, 12-01-2012). Actors as PRW, the NIOZ deputy director and the municipality of Texel saw opportunities to optimise the design such that costs could be lowered. All actors involved agreed that the technical study did not hold the optimal design for a sandy seaward solution, therefore a follow-up study is conducted with an optimized design. The final decision of how to strengthen the dike in the Prins Hendrikpolder will be made in the dike reinforcement plan, based on conclusions from the different knowledge arrangements.

Finally, we summarize our interpretation of engagement *across the* key organizations involved in this knowledge arrangement focusing on the technical study, in table 1.

Table 1. Degree of engagement across organizations in different activities of knowledge development (-- = very little engagement, ++ = very much engagement).

Activity	Engagement across organisations	Subjects	Gap theory – practice
Problem formulation	+ +	Sketch plan, formulation assignment Witteveen+Bos, agreed research questions	Agreement on assignment and research questions
Methods and techniques	+	Usage of multiple methods, erosion versus sedimentation	Agreement on sketch design, incorporation new data and methods
Interpretation of results	- -	Draft versions report, formulation of conclusions	Disagreement design and costs
Choice of solution	+	Optimisation possibilities	Agreement for further research

In conclusion, the knowledge arrangement for a sandy seaward solution is organized around three forms of feasibility: legal, technical, and financial feasibility. By focusing on seaward solutions a different discourse of seaward thinking is advocated in this arrangement in comparison to the project arrangement (sober, effective, robust). The knowledge arrangement does not fit properly in current legislation, consequently it demands a flexible approach towards legislation, funding, and design. The causal mechanisms affecting a process of engaged knowledge development for a sandy seaward solution are discussed in the next section.

3.3 Causal mechanisms engaged knowledge development

Based on the dynamics observed in the project and knowledge arrangement we present seven causal mechanisms that affect a process of engaged knowledge development. Those mechanisms are derived in the third round of our coding procedure (selective coding) and can be linked to the various dimensions in an arrangement. The causal mechanisms describe the mechanisms that link different causes to the effects upon engaged knowledge development. They are found at two levels: within a knowledge arrangement, and between a project and knowledge arrangement.

Within a knowledge arrangement we consider two mechanisms: involving multiple perspectives, and limited technical knowledge.

Mechanism 1 involving multiple perspectives

Multiple perspectives of actors are involved in the different activities of knowledge development in the technical study of a sandy seaward solution. Perspectives mix, and views are exchanged. This resulted in broad support among actors for the sketch plan, and altered insights in which methods and techniques to be used. In contrast, activities in which multiple perspectives were hardly involved (interpretation of results) resulted in critical feedback on the estimated costs and design of the seaward solution.

Mechanism 2 limited technical knowledge

Actors as PRW and the municipality of Texel have limited technical knowledge and find it difficult to comment upon the technical study. This possesses challenges to a process of engaged knowledge development as actors lack technical knowledge but understand that the study resulted in an expensive (and therefore unfeasible) design. By consulting an expert within their coalition – the NIOZ deputy director - they are able to jointly formulate opportunities to optimize a sandy seaward solution. These opportunities resulted in a follow-up study.

Between the project and knowledge arrangement we consider five mechanisms that affect engaged knowledge development: trusted partners, scope demarcation, time pressure, sharing responsibilities and nesting. These mechanisms demonstrate different aspects of the strong connection between the project and knowledge arrangement.

Mechanism 3 trusted partners

Witteveen+Bos is a trusted partner of HHNK. The two actors cooperate closely in the project arrangement and in other knowledge arrangements of landward and innovative solutions. As HHNK is content about the functioning of Witteveen+Bos, they are also conducting the technical study. Witteveen+Bos allows the involvement of other actors for smaller sub-parts of the study. This hampers a process of engaged knowledge development as the study is subdivided into smaller parts for different actors.

Mechanism 4 scope demarcation

The scope for knowledge development is demarcated at different levels through the discourses expressed. The project scope “reinforcing the dike within limits of time and money” already sets initial boundaries for knowledge development, extensive research for several years is for example not an option. During a joint government meeting in the project arrangement the scope for knowledge development in the technical study was formulated, being a sandy solution that replaces the existing primary flood defence. Within the knowledge arrangement, Witteveen+Bos demarcates the scope for actors who conduct sub-parts of the study. Through scope demarcation boundaries are drawn what can and cannot be investigated, having consequences for which parties should be involved in knowledge development.

Mechanism 5 time pressure

Time serves as a pressing resource in the project arrangement, and results in time pressure in the knowledge arrangement. The conducted technical study has a global character, respondents state they had limited time to comment on the study, and there was no time for an optimisation discussion until the study was finished. Paradoxically this may have caused additional delay as an optimisation study was conducted after the technical study was finished.

Mechanism 6 sharing responsibilities

Current legislation makes HHNK responsible for the overall dike reinforcement project. HHNK considers itself core responsible for the technical study as it is one of the alternatives studied in the EIA procedure. Consequently the report and conclusions are written by HHNK and

Witteveen+Bos. This results in little opportunity for engagement of other actors related to the interpretation of results.

Mechanism 7 nesting

Over time the knowledge arrangement of a sandy solution became more and more nested in the project arrangement. Initially the knowledge arrangement challenged the project arrangement, but over time the discourse of seaward solutions became part of the project arrangement and enriched the scope of the project. Initial ideas were transformed into a written response, which was visualized in a sketch design that served as point of departure for the technical study. The original initiators (Municipality of Texel, NIOZ deputy director) lost their control over the seaward solution the more it became part of the project arrangement. Consequently they are less involved in knowledge development for the sandy solution compared to initial activities, but their ideas are now incorporated in the project.

4. DISCUSSION

Much research focuses on knowledge development within one organisation (Nonaka and Takeuchi 1995) or project organisation (Love, Fong et al. 2005; Ratcheva 2009). However we adopt with engaged knowledge development another perspective upon knowledge development in an engineering project's setting, as policymakers, researchers, and other stakeholders can be involved and influential in knowledge development. Especially when a project is closely tied to the public domain, as is the case for coastal defence (this paper), or mining (Runhaar and van Nieuwaal 2010).

The conceptual framework developed in this paper builds upon the framework introduced by (Hegger, Lamers et al. 2012). We made an innovative distinction between project arrangements and knowledge arrangements, to be able to analyse engaged knowledge development in a project's context. The importance of the context – being the project organisation - in which knowledge is developed is highlighted by various authors (Nowotny, Scott et al. 2001; van Buuren and Edelenbos 2004). As our framework focuses on engagement between organisations, we are not able to analyse knowledge development on an individual level within an organisation e.g. (Love, Fong et al. 2005; Nonaka and Krogh 2009).

The mechanisms discussed in this paper operate within one project. Separately, these mechanisms reflect diverse bodies of knowledge such as social learning (mechanism 1-2), inter-organizational collaboration in networks (mechanism 3 and 6), discursive analysis (mechanism 4), and project management (mechanism 5). Yet a key contributions of this study, is both the notion that this set of mechanisms exists within one project, as well as their impact upon engaged knowledge development. These mechanisms of engaged knowledge development can be useful for members of a project organisation, as they can offer strategies for management and intervention in processes of engaged knowledge development.

Our research generates new questions for processes of engaged knowledge development in coastal defence projects. First, we should analyse the causal mechanisms further in order to isolate them from each other as much as possible. Under which conditions are they activated, and what is their effect upon knowledge development? The more we understand the functioning and importance of different mechanisms, the better we can estimate their relative importance. Different authors mention the technique of process tracing as a powerful source for causal inference (Gerring 2007; Bennet 2010). Second, research into other coastal defence projects is required. As (Turnhout, Hisschemöller et al. 2008) argue, different arrangements result in different modes of knowledge development. It would be interesting to explore how a different project arrangement affects a knowledge arrangement, and whether different causal mechanisms operate in these arrangements. Third, the mechanisms presented in this paper can be analyzed further in other cases. To what extent do they operate in other coastal defence projects? Is it possible to determine which mechanisms are really influential on a process of engaged knowledge development? Finally, when we better understand the importance of causal mechanisms in different arrangements, we could present recommendations for arrangements that can ultimately narrow a gap between theory and practice in coastal defence projects.

5. CONCLUSION

Our analysis holds three important implications for understanding a process of engaged knowledge development in engineering projects during their planning phase. First, empirical results in this paper suggest that the gap between theory and practice can be narrowed through engaged knowledge development in all four activities of knowledge development: problem formulation, methods and techniques, interpretation of results, and choice of solution. The knowledge arrangement of a sandy seaward solution shows that involving researchers, policymakers and stakeholders in three activities of knowledge development resulted in broader support, thereby narrowing the gap between theory and practice. Little engagement in one specific activity (interpretation of results) leads to discussions and opposition against the main conclusions of the technical study. The adopted design was too expensive and could be optimized further. This suggests that engagement between actors in all activities is required to narrow a gap between theory and practice through knowledge development.

Second, different mechanisms exist between a project and knowledge arrangement that complicate a process of engaged knowledge development. Consequently they hinder a narrowing of the gap between theory and practice in several ways. Actors become trusted partners conducting the major share of knowledge development, discourses demarcate the scope for knowledge development too narrowly, time serves as a pressing resource, and rules allocate full responsibility to one actor.

Third, we saw how a strict project arrangement fuelled the development of a new knowledge arrangement. The strict character of the project is reflected in the relevant legislation, the fierce criteria related to solutions, funding and deadlines, and the tight supervision by HWBP and the House of Representatives. Initiating actors in the knowledge arrangement organized broad support for a sandy seaward solution and found funding for research outside the existing project arrangement. The knowledge arrangement is more flexible as it does not fit in current legislation, demanding a flexible approach towards legislation and funding. Consequently the design changes over time and new actors are involved when thought necessary. The dominant discourse in the project arrangement initiated the development of a new knowledge arrangement, involving other actors advocating a different discourse. Over time this new knowledge arrangement became more nested in the strict project arrangement, thereby broadening its scope and transferring responsibility from the original initiators to the water board.

The quest to develop relevant, engaged knowledge in engineering projects during their planning phase is maybe a long one. Any project organization has to manage many challenges. They have to deal with biophysical and social-economic dynamics of the environment in which it wants to construct a solution, has to comply to strict legislation, tight schedules and budgets. On top of that, organizing a process of engaged knowledge development might receive little attention and can easily be conceived as just another burden for a project's organization. Yet, as this paper illustrates, engaged knowledge development is worth the additional effort as it results in more relevant knowledge and solutions that receive broad support from the actors that were involved in developing that solution.

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ANNEXES

Annex 1 Operationalisation of dimensions in conceptual framework and interviews.

Dimension	Indicator	Topics in interview
Actors	Actors involvement	Involvement and role of actors
	Actors relations	Relations between actors, cooperation with other actors
	Actors affected	Who is affected
	Actor coalitions	Cooperation between actors, on which subjects, motives for cooperation
Rules of the game	Access rules	Why is an actor involved
	Allocation of responsibilities	Responsibilities of actor, reasons for responsibilities
	Legislation and policy rules	Relevant legislation and policy
	Interaction rules	Frequency and type of contact between actors
Resources	Time	Relevant time period, Time spend, time given,
	Money	Budgets spend
	Information	Available and missing information
Discourses	Project rationale	Reason for initiation, important characteristics
	Project solutions	Opinion about coastal defence solutions
	Coastal Defence	Opinion about coastal defence
Knowledge development	Problem formulation	Purpose, topic, relevance and research questions
	Methods and techniques	Possible methods and techniques
	Interpretation of results	Interpretation of results, formulation of conclusions
	Choice of solution	Choice for solution

Annex 2 Conducted interviews

Date	Actor	Interviewee	Interview scope
13-12-2011	Witteveen+Bos	Hans Helder	Project arrangement
14-12-2011	Towards a Rich Wadden Sea	Wim Schoorlemmer	Knowledge arrangement
15-12-2011	HHNK	Tanja Heringa	Project arrangement
15-12-2011	HHNK	Edwin Meisner	Project arrangement
22-12-2011	Municipality of Texel	Pieter de Vries	Project arrangement
12-01-2012	Municipality of Texel	Pieter de Vries	Knowledge arrangement
16-01-2012	Province of Noord-Holland	Peter Boon	Project arrangement
24-01-2012	HHNK	Edwin Meisner	Knowledge arrangement
20-01-2012	Witteveen+Bos	Hans Helder	Knowledge arrangement
20-02-2012	NIOZ	Herman Ridderinkhof	Knowledge arrangement

Annex 3 Key elements of described project arrangement and knowledge arrangement

Project arrangement	Actors	HHNK, Province Noord-Holland, Municipality Texel, HWBP, House of Representatives, Witteveen+Bos, various NGOs in advisory group
	Rules	Water Act, Nature Protection Act, Environmental Management Act, National Water Management Agreement, Spatial Planning Act
	Resources	HWBP and HHNK co-finance the project. Delivery deadlines are not met, and costs rise over time
	Discourses	The dike does not meet current safety norms and has to be strengthened. Reinforcements have to be sober, robust and effective.
Knowledge arrangement	Actors	HHNK, Province Noord-Holland, Municipality Texel, PRW, Eelerwoude, NIOZ deputy director, village committees, nature organisations
	Rules	Nature Protection Act and Water Act
	Resources	PRW and municipality of Texel finance research
	Discourses	Sustainable seaward solutions for coastal defence at Texel