



Article title: Tacit knowledge in water management: a case study of Sponge City

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Many studies have identified challenges of blending two or several disciplines and fields of studies involved in environmental and water management (Barron et al., 2017; Bell, 2014; Brown et al., 2009; Cosgrove and Loucks, 2015; Dhakal and Chevalier, 2017; Qiao et al., 2018). This study zoomed in on a root cause of these challenges – the difficulties regarding the communication of knowledge between actors. The theory of tacit knowledge has not been previously deployed to explain the underlying causes of difficulties in delivering interdisciplinary and cross-sectoral projects in the context of urban water management. To fill in the gap, sociological tools were used in this research to study how water professionals are able or unable to communicate effectively due to the tacitness of knowledge being transferred. This paper uses the Sponge City programme of urban water management in China as the site of study. There are three prominent contributions made by this study. First, the meaning of tacit knowledge is clarified and applied to sustainable water management. Second, different connotations of tacit knowledge in the context of urban water management are delineated based on the means and tools needed for its communication. Third, examples of each type of tacit knowledge according to the terrain of tacit knowledge are identified, and potential of having urban planners as knowledge brokers is explained. The insights from this research are relevant for Sponge City as well as integrated urban water management at large. The study considered the interrelationship of knowledge transfer and urban water management in social, economic, political, and cultural contexts.

Tacit knowledge in water management: a case study of Sponge City

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Abstract: Sustainable, resilient urban water management is fundamental to good environmental and public health. As an interdisciplinary task, it faces enormous challenges from project complexity, network dynamics, and the tacit nature of knowledge being communicated between actors involved in design, decisions and delivery. Among others, some critical and persistent challenges to the implementation of sustainable urban water management include the lack of knowledge and expertise, lack of effective communication and collaboration, and lack of shared understanding and context. Using the Chinese Sponge City programme as a case study, this paper draws on the perspectives of Polanyi and Collins to investigate the extent to which knowledge can be used and exchanged between actors. Using Collins' conceptualisation of the terrain of tacit knowledge, the study identifies the use of relational, somatic, and collective tacit knowledge in the Sponge City pilot project. Structured interviews with 38 people working on a Sponge City pilot project provided data that was rigorously analysed using qualitative thematic analysis. The paper is original in using theories of tacit knowledge to explain barriers and pathways for information and messages being communicated between actors in urban water management. The methods and results provide the groundwork for analysing the access and mobilisation of tacit knowledge in the Sponge City pilot project, with relevance for other complex, interdisciplinary environmental projects and programmes.

Keywords: Sponge City; Tacit knowledge; social capital; China; Integrated urban water management; knowledge transfer; urban planning

1. Introduction

Sustainable urban water management aims to deliver safe, reliable and secure water and sanitation services, by mobilising stakeholders to ensure good public health and improve social, economic, and ecological outcomes (1–3). Sustainable approaches encourage integrated management of water supply, stormwater and wastewater infrastructure, and stronger integration of water with urban design and decision making. Working in urban water management demands the ability to work with professionals from other disciplines, including the ability to communicate complex ideas with people who do not share background knowledge (4). More than a decade ago, Brown et al. (5) found that planning for stormwater management in Australian local government was dominated by engineering consultants, and project implementers did not have the skills, expertise or mentality required to work with non-technical communities. More recently,

Cosgrove and Loucks (4) commented that stakeholder engagement and interdisciplinary working are yet to be achieved in urban water management, calling for water managers be involved in the earliest stages of urban planning to enable productive interaction with other sectors.

Sustainable approaches to urban water management are increasingly relevant as cities around the world address challenges of climate adaptation, resilience and growing populations (1), leading to ever higher recognition of the importance of inter-disciplinary interaction and coordination (6). In China, Sponge City is a flagship initiative implemented by the central government to promote a more sustainable and healthier environment, focussing on urban stormwater treatment and control (7,8). The city as a “sponge” is adaptive and resilient to changes in the environment, especially during high rainfall events (7). The Sponge City is resilient to flooding by optimising the design of urban landscapes to capture and disperse water, including increased use of green infrastructure measures such as rain gardens, green spaces and wetlands. The foundation of the Sponge City concept is similar to international models such as Low Impact Development (LID) and Best Management Practices (BMP) in the United States, Sustainable Urban Drainage (SUDS) in the United Kingdom and Water Sensitive Urban Design (WSUD) in Australia (1).

Since it began in 2014, the Sponge City initiative has faced a variety of challenges in design and planning, implementation, construction, management and evaluation. Pilot cities were chosen to represent a wide range of social, economic, and environmental statuses, and each city was anticipated to approach the projects with different perspectives and expectations (9). However, universal challenges have been experienced in most pilot cities resulting from knowledge gaps across different sectors and disciplines, which may lead to misinterpretation of objectives and requirements, over-simplification or complication of problems and solutions, as well as implementation gaps (10).

Tacit knowledge is difficult or impossible to communicate on paper, and is often neglected in interdisciplinary, cross sectoral project planning and implementation (11). Knowledge is kept tacit due to barriers that arise because of differences in perspectives, responsibilities, and interests (12), differences in capacities, capabilities, and thought and learning processes (13,14), as well as physical constraints such as lack of time or facilities. Acknowledging debates surrounding definitions of tacit knowledge and the mismatch of epistemic and tacit concepts of knowledge (15,16), this study adopts a pragmatic stance to tackle the problematic situation where some forms of knowledge are more difficult to communicate and comprehend than others.

This paper distinguishes the types of tacit knowledge, identifies and categorises them in the context of a Sponge city pilot. It is original in its focus on the importance of tacit knowledge gaps between professionals with different backgrounds and experiences. The paper begins with an overview of the definitions and theories of tacit knowledge, and its relevance to urban water management. This is followed by a description of Sponge City, outlining the main aims and rationale of the initiative as well as the obstacles in interdisciplinary and inter-sectoral communication and learning. Next, the rigorous qualitative research design and data analysis

methods are defined. The next section discusses the findings and provides some conclusions and recommendations for future work.

2. Tacit knowledge and sustainable urban water management

Urban water systems are comprised of a variety of components, from the treatment of water for different purposes to the draining of rainfall runoff from the urban streets. The difficulty of water management does not only reside in the structural and technical complexities; urban social dynamics create layers of complications and uncertainties. It is a complex system made up by multiple disciplines and professions, each occupying a niche environment and commanding niche knowledge that is difficult to communicate with each other.

Many studies have identified challenges of multi-disciplinary working in urban water management. Challenges relate to policy, resources, governance, and individual and societal perceptions, attitude and behaviours (4,17–21). This study zoomed in on a root cause of the above-mentioned challenges – the difficulties regarding the communication of knowledge between actors. More specifically, tacit knowledge is especially difficult to communicate with others, since it is embedded in each person’s perspective and experience, and mobilised by interactions within social networks.

Polanyi argued in the book *The Tacit Dimension* (22), that all knowledge relies on personal judgement, and more specifically that “we can know more than we can tell”. While he invigorated the discussion on the role of personal experiences in sharing of scientific knowledge in the well-known book *Personal Knowledge Towards a Post-Critical Philosophy* (23), the theoretical framework of this research is inspired mainly by his theoretical positions outlined in the book ‘The Tacit Dimension’. He spoke of “knowing” – the “knowing what” and the “knowing how”, to cover both theoretical and practical knowledge (22). Knowledge is an activity that should be described as the process of knowing, and tacit knowing is a “tacit power”, or “an act of integration” (15). Polanyi further explained that we could communicate our knowledge provided we are given adequate means for expressing ourselves, whether it can be understood by others rely on other people’s intelligent co-operation for catching the meaning of the “demonstration” (22).

In Polanyi’s (22) original conceptualisation of tacit knowledge it is deeply personal, held within the body and unable to be made explicit. Two characteristics of knowledge are highlighted by Polanyi, that it relies on personal judgment, and we can know more than we can tell. In his articulation of the concept, all knowledge is either tacit or rooted in tacit knowledge, ruling out the possibility of drawing a clear boundary between “tacit” and “explicit” knowledge. The concept of tacit knowledge began with Polanyi as he placed scientific knowledge and rational thinking back into the environmental, social, cultural, and personal context surrounding the knowledge.

Nonaka (24) emphasises the importance of socialisation processes in sharing knowledge situated along a tacit-explicit knowledge spectrum. Nonaka and Takeuchi described one of the processes to

make tacit explicit; the SECI¹ process is an effective pathway of knowledge conversion in a closed network where the knowledge is mostly bounded within the actors of an organisation. In response to controversies regarding the theory of knowledge creation and the knowledge conversion process, Nonaka and von Krogh (25) gave more clarification on how knowledge conversion incorporates the dynamic interaction between tacit and explicit knowledge. They recognised that tacit and explicit knowledge is along a continuum while being able to “momentarily take on different forms”. In their view, the ability to transform is significant because the explicit form of knowledge is more enriched, and the process of making it explicit articulates the tacit knowledge and expands one’s boundary of understanding.

Similar to Nonaka, Collins emphasises the importance of socialisation, but Collins’ terrain of tacit knowledge provides a broader framework of analysis, expanded from Polanyi’s conceptualisation of tacit knowledge. In Collins’ view, “tacitness” is a continuous spectrum from “weak” to “strong”, and its strength is determined by the extent to which the knowledge is programmable and have the use of knowledge reproduced in machines (26). Collins argued that although all tacit knowledge is obtained by humans through interacting in society, there are different ways to acquire it. When Polanyi described *tacit* as what we can know more than we can tell, Collins emphasised that tacit could be either “understood or implied without being expressed directly”, or it could also be “cannot be explained”.

One kind of tacit knowledge is somatic-limit tacit knowledge, where the biological limitations of the human brain and bodies can only process knowledge that has not yet been converted to explicit rules, for example, one can formalise the rules for balancing a bicycle, and yet one does not apply these rules when acting out the riding of a bicycle. Another kind is collective tacit knowledge, which one cannot make explicit because it is located in the human collectivities, so the only way to acquire it is to be embedded in a specific society (27). A third type described by Collins is relational tacit knowledge, a supposedly “weaker” type of tacit knowledge. These pieces of knowledge are on the borderline of explicit and tacit. They are categorised as “tacit” knowledge by Collins because they can be but are not made explicit for various reasons.

¹ SECI refers to the process of knowledge conversion proposed by Nonaka and Takeuchi (1995). Socialisation transfers tacit knowledge by sharing and creating tacit knowledge through direct experience. Externalisation converts tacit knowledge to explicit by articulating tacit knowledge through dialogue and reflection. Combination transfers explicit knowledge by systemising and applying explicit knowledge and information. Finally, internalisation converts explicit to tacit knowledge by learning and acquiring new tacit knowledge in practice.

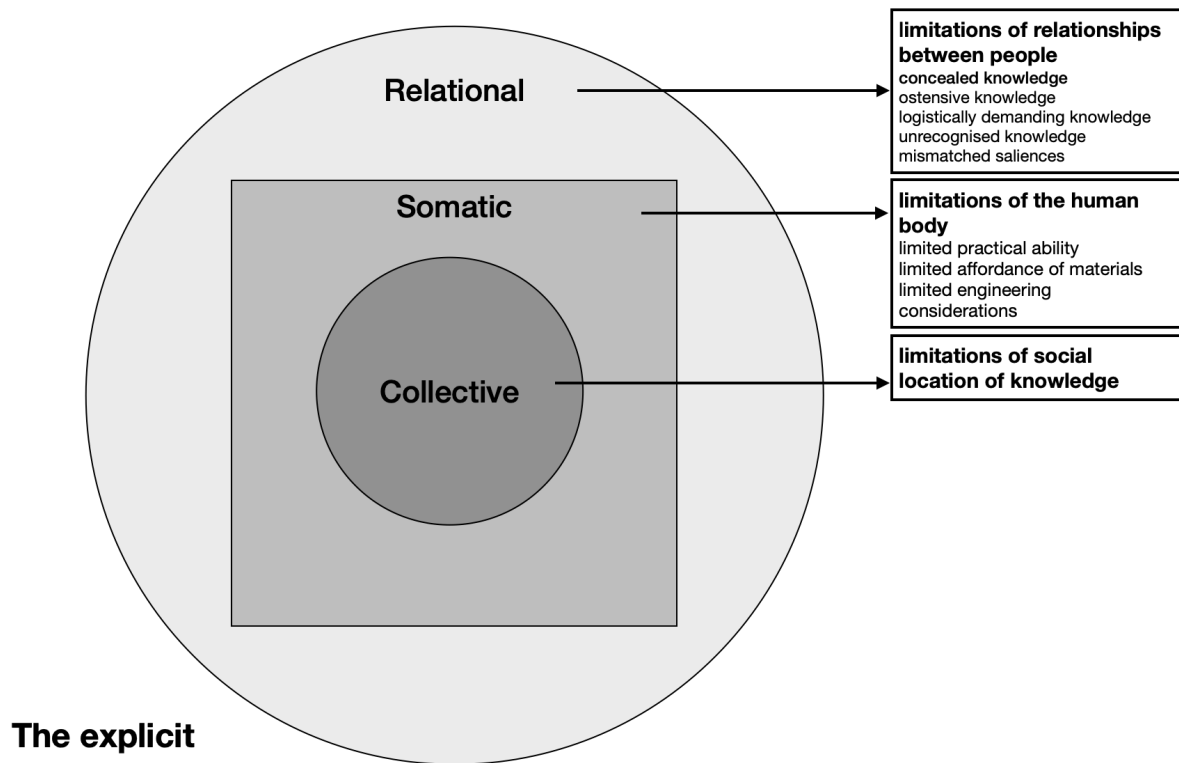


Figure 1 Terrain of Tacit knowledge by Harry Collins

3. China's Sponge City programme

Sponge City is a national programme in China, which is a joint initiative of the Ministry of Finance, Ministry of Housing and Urban-Rural development, and Ministry of Water Resources. Initially targeting urban stormwater treatment and waterlogging control, it evolved to be a national strategy to achieve a “new-type of urbanisation” and “overall construction of a well-off society” for China (28). The first batch of 16 “pilot cities” were selected in 2015, and a further batch of 14 “pilot cities” were selected in 2016. Similar to other programmes in integrated urban water management, Sponge City encourages the practice of the “naturalisation” of the urban water cycle, diversification and decentralisation of water sources and infrastructure, consideration of water conservation and resource efficiency, and integration of water sub-sectors within cities and beyond, as well as engagement with other sectors and communities (7,12,29,30).

Water management in Chinese cities reflects large regional differences in climate and historical practices (31–33). Compared to the southern Yangtze River basin, where water resources are abundant and stable, the north of China experiences a high seasonal variation of precipitation and much lower per capita water availability (34). By comparing the water supply and management practices of Beijing and Shanghai, Cosier and Shen (31) found that the environmental and economic contexts account for the differences in their approaches towards the implementation of national policies and regulations. Specifically, northern cities such as Beijing tend to have a better implementation of planned water use and water-saving systems, while southern cities that are

more abundant in water tend to be better at adopting water supply and use contracts because they have fewer incentives to restrict water consumption.

Integrated urban water management in China has been interpreted as the unification of all water-related administrative units under a single ministry, rather than holistic management of urban water cycle in coordination of hydrological cycle with inter-disciplinary and inter-sectoral efforts. To achieve stronger integration of urban water management using the Sponge City concept, there needs to be an alignment of interests, objectives and knowledge capacity at all levels. It is not the lack of willingness to introduce the Sponge City concepts into local government planning agenda that warrants concerns, but rather is the potential lack of knowledge and support needed by the local authorities to adhere to the water management principles as outlined in the national policy.

While many disciplines that are not traditionally involved in urban water management or drainage design are more present in Sponge City projects, actors are facing the challenge of collaborating with disciplines that they never had to work with before. The Sponge City requires a higher level of trans-jurisdictional collaboration and coordination, as well as a higher level of inter-disciplinary and inter-sectoral communication and learning. Therefore, it is necessary to understand the factors that influence how Sponge City actors, with different worldviews and technical language, acquire and exchange tacit knowledge.

4. Methods

A series of semi-structured interviews was conducted over three months with 38 people, to measure "how knowledge is being shared" in a Sponge City pilot city. The interviews explored various levels and types of knowledge possessed and used by the actors, the mechanism, and the quality of their interactions during the projects. During the interviews, the actors were asked to identify other actors with whom they interacted and exchanged information. The participants were not asked to recall the names of individual actors. Instead, they identified the organisations or groups of individuals. Interviews were transcribed and analysed to build a network of connections for each participant and to identify key themes in how participants described knowledge communication and learning within the Spon

ge City programme.

The actors interviewed can be divided into five groups based on their professions, as determined by the type of organisation in which their work is based. The groups are: university (U), government (G), private sector (C), professional organisations (P). The distinction between companies and professional organisations is made by whether an organisation is affiliated with a government bureau or commission; if not, then it falls under the "private sector" category. Many actors work under different titles and the group that the actor belongs to derives from his or her main title.

Using NVivo 11 Pro software, an initial round of coding was conducted in the original language to preserve meaning and avoid misinterpretation. This round of coding was deductive, where pre-

determined codes were derived from the Sponge City guideline (7) and the interview questions. Hereafter, an inductive coding process was carried out as themes emerge from the interviews; at this stage, many codes were collapsed into more condense categories. Then, another deductive process of coding was completed, using more meaningful units of analysis derived from Collin’s conceptualisation of tacit knowledge.

5. Results and Discussion

The Sponge City case study demonstrates that sometimes it is the actors’ inability to articulate or comprehend a piece of knowledge that destroys the building of a network that is inducive to knowledge transfer. From relational to collective, the conditions that need to be changed in order for the knowledge to be made explicit become more complex and difficult to satisfy. Using the terrain of tacit knowledge conceptualisation, this section demonstrates various types of tacit knowledge that emerged from the interviews with the Sponge City actors and discusses the possible causes for knowledge to become or remain tacit.

Figure 2 describes the different types of relational tacit knowledge, with the innermost being the strongest type. The senders and receivers of relational tacit knowledge share enough cultural similarity and what is at notable is how they relate to each other due to personal inclinations or the those acquired from their social groups (26). The stronger the tacit knowledge, the more difficult it is to “eliminate the contingencies of human relationships, history, tradition and logistics” (26)(p.98).

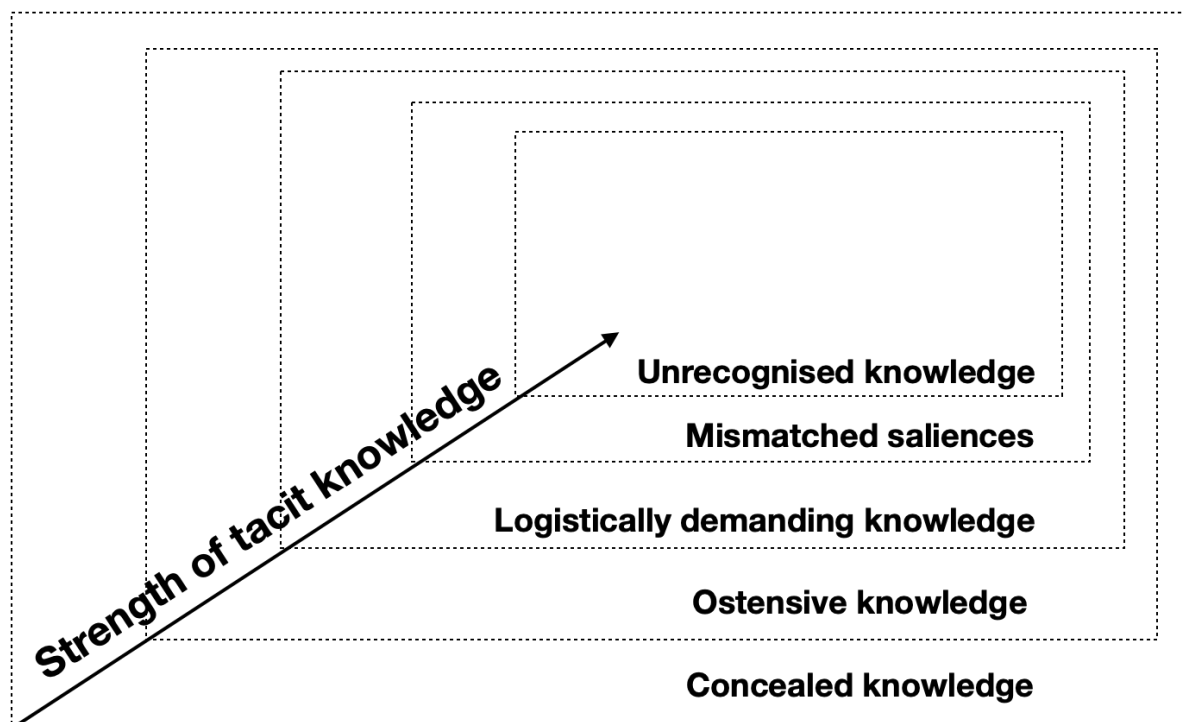


Figure 2 Strength of relational tacit knowledge derived from Collins (26)

5.1 Relational tacit knowledge

Relational tacit knowledge refers to knowledge that is intentionally hidden, is not revealed due to contingencies of time and place, or is unintentionally concealed without realising other people don't understand it. Collins (26) characterises this type of tacit knowledge as “weak” tacit knowledge.

Concealed knowledge, just as indicated by the term, is kept hidden or a “secret”, and thus being not transferred from one person to another. This type of knowledge sits on “the borderline of the explicit and the tacit (26) (p.93)”, and the conversation from tacit to explicit can happen by including the sender and the receiver of information in the same conversation or located in the same framework of time and space. The interviews showed that the most common causes for knowledge to be held back are the lack of direct ties between actors and the lack of trust to motivate communications.

Urban planner, C17, and civil engineer, P1 revealed in the interviews that difficulties of identifying with another person or group of people prevented them from being more open to cooperation and learning, and from developing trust in another person or group of actors. Also, the level of communication is high between actors from the same unit of the same organisation. Due to the familiarity with one another in the group, personal relationships foster a high level of trust between these actors. Moreover, they are likely to be governed by the same social norms, which also facilitates their willingness to be open to communication and cooperation.

Many of the actors interviewed found the act of learning and communicating hindered the quality of exchanges. What also made knowledge transfer and learning difficult, is the inability of actors to adequately explain a concept to another individual who has a different knowledge background. Many said that they either could not find the right way to get their messages across, or their colleagues could not perceive the need for additional explanation or understand the point of confusion. This is an example of the challenges in communicating ostensive knowledge, where the actors must go beyond using description in words and involve connections through other senses, such as the showing of an artefact (26).

Even when the actors are not intentionally or unintentionally hiding any “secret” knowledge, sometimes the task could be too logistically demanding for actors to carry out. Actors U5 and U6 explained that a good way to collaborate is to let each group or unit carry out their own tasks and come together. In these cases, the actors expected the collaborators to demonstrate competent skills within their own expertise, and such trust dwindles for other types of tasks. However, while this type of relationship enables better a collaboration process, this type of manifestation of trust limits knowledge exchange and combination between actors from different disciplines, for the actors did not engage in social exchange or learn beyond the already codified knowledge.

There was also knowledge being kept tacit due to mismatched salience and unrecognised knowledge. If the knowledge is not concealed, too complex to be described, or logistically

demanding, the transfer of knowledge may be contingent upon a person recognising the values of knowledge they possess, or the knowledge possessed by another person. C12 is an urban planner but working on Sponge City plans required her to have some understanding of topics such as hydrology and urban flooding. Despite working on the same project in the same office, she was not as able to learn as much as she would like to from her colleagues who were the experts on the water topics. Previously, it is shown that time and effort are required to assimilate and exploit new knowledge, the interviews revealed that the task of explaining becomes more complicated when there is not enough overlapping of knowledge between the actors. Designer C19 had similar experiences in another company. As a landscape designer who has had experience working on water models before, she struggled to explain certain concepts and indices used in the models to other designers who did not have prior knowledge of water modelling.

C9 is from a construction background and has abundant experiences working with various designers. Although this was his first time working on green infrastructure construction, he is a very experienced construction team manager that has worked with designers on various types of building construction before. This experience allowed him to communicate effectively with the design engineer and “work out everything”. C9 was able to carry out the construction based on the design since he could communicate effectively with the designer and have her help on the interpretation of the construction drawing. Knowledge was transferred between the designer and the construction engineer because the designer was familiar with the construction drawings and how to interact with construction teams. In comparison, C12 and C19 were not as successful because firstly, the overlap in disciplinary-specific knowledge between the actors is smaller while the complexity of learning is higher; secondly, both sides were not familiar with conducting such in-depth explanations of concepts to collaborators from different disciplinary backgrounds.

While the previous cases demonstrate knowledge being concealed due to mismatched saliences between actors, knowledge can also be concealed because neither of the actors recognise the value of what they know. U9, who was a researcher and designer from a different project, believed that the material suppliers should make decisions according to the design, instead of the other way around. While participants expressed that it was important to have an interdisciplinary project team, they had different opinions about actors from other project stages. One considered the suppliers to be collaborators and exchanged knowledge with them, while another one was of the opinion that the suppliers didn't have anything valuable to offer him since they are experts from drastically different fields.

5.2 Somatic tacit knowledge

Whether somatic tacit knowledge can be made explicit is limited by the capacity of the human body, which means it could be more difficult to eliminate the contingencies; however, it is not necessarily more difficult to communicate compared to relational tacit knowledge (26). The bike riding example Polanyi (22) described is an example of somatic tacit knowledge, because this is a

type of knowledge that cannot be reproduced simply by providing a set of written instructions or something similar.

All the actors interviewed agreed that planners play an important administrative and strategic role in guiding the Sponge City projects, and the guidance they produce has the potential to provide a common code and language for actors in other project stages. However, the reality was different in that the guidance was regarded to be not sufficient (C15) and unclear (C13) to follow. Actors tend to find communication to be smoother when the governmental actors have either been introduced to the language in past projects or are becoming familiar with the use of codified information in the form of guidelines and standards, as well as by learning during their current projects.

G1, a government actor, recounted that to prepare for their city's pilot city application, they approached the research team in a renowned university because they wanted to collaborate and learn from them. They have since then formed a good working relationship, and actors from both sides expressed during the interviews that they appreciated each other throughout the process. Another example of successful communication and knowledge exchange was told by U1, an actor from research and design background. During her interaction with government actors, she noticed that some of them started to pick up on the vocabulary as the project went on, and began to apply their newly acquired knowledge to ask questions and offer their opinions during project meetings.

5.3 Collective tacit knowledge

Going one step further, there are certain types of knowledge contingent upon factors or conditions existing in the collective society. Collins (26) pointed out that "the individual is a temporary and leaky repository of collective knowledge" (p.133). Any adaptation and comparison between Sponge City and other international sustainable urban water practices should consider the social circumstances and society's unspoken rules.

In his book 'The Water Kingdom', Philip Ball drew attention to the historic anthropocentric view of the environment and nature in China. From the ancient Confucian's idealism to the recent history of dam building, Ball claims that the culture itself is not inductive to environmental protection and preservation, whilst also holding that "none of this suggests that there is something uniquely bad for the environment about an authoritarian, socialist form of government (35) (p.296)". Cultural factors and the attitudes and behaviours that they are shaping should not be targeted as the root cause of challenges that arise when trying to implement integrated urban water management in China, but it is still necessary to consider the means to guide a shift in the culture that governs the relationship between water professionals (19,36,37).

In recent sustainable urban water and urbanisation projects in China, such as the eco-cities, there are several noticeable characteristics of policy implementation and environmental governance. At first glance, environmental governance in China seems to be top-down, command and control, or authoritarian, where national regulation dominates and policy process tends to be non-participatory (38,39). A closer look at the national and local government relations can reveal that

policy implementation in China is more complicated than previously anticipated by both researchers and the national government. China's water resources management adopts policies and laws that are centrally set and locally administered, where multi-level jurisdictional framework (national, provincial, prefecture and county levels of administration) is combined with a catchment-based approach to river basin management (31). This is a very complicated situation for water management. While all agencies at a central level have corresponding line agencies at the provincial, prefecture and county levels, who in turn look to the national agencies for technical guidance and implementation of laws, these agencies report administratively to the local governments (34). The Chinese administrative structure can be characterised by "a line (tiao)" and "a block (kuai)". The "line" refers to hierarchical relations from the Communist Party of China (CPC) committee down to the provincial government, while the "block" refers to the government network at the provincial and city level. The "block" exists because the local governments have considerable autonomy over their own policies. Therefore, it is not guaranteed that the intent of the central government can be met with a similar level of implementation support from the local government. It creates another layer of complexity for integrated management because each party involved may have different or even conflicting priorities and objectives.

Cities in China have inherited their own water culture and remnants of physical structures of historical waterworks, and they influence their modern-day practices to different extents. As a city chosen for the Sponge City pilot program, Ningbo has a long history with what can be described as "blue-green" water management. Early in the city's history, water control works were constructed using natural materials such as stone, mud, and soil, where plants used for reinforcement were able to stabilise the soil and provide food for the silkworm (33). At the time, the system of small waterways and waterbodies supported biodiversity while meeting the society's needs for irrigation, freshwater and drainage, but urbanisation and industrial development caused a shift from "natural" to grey infrastructure, and the surface water network functions primarily as urban drainage and flood control as agricultural lands are converted to impervious surfaces (Ibid). What happened in Ningbo was experienced in most of the urban centres as they developed and modernised, but Ningbo has a rich history of sustainable water management which bequeathed the city engineering and cultural assets that may still be useful today.

5.4 Role of urban planners as knowledge brokers

Knowledge can be kept concealed due to lack of trust between actors. While a good relationship between actors can increase the opportunities for engaging with others to access and transfer knowledge, as well as increase an actor's expectation and confidence in the value of new knowledge to be gained through the exchanges. A more considerable impact of having a good relationship between the actors is on their motivation, or willingness, to engage with others in learning and knowledge exchange activities (40). Sequentially and temporally, planning is placed at the top of the Sponge City network. Actors in other stages of the project may or may not have a direct relationship with the plan makers, but they are all indirectly linked with planners via the

documents they produce. However, a tie between planning and design may weaken for various reasons.

To fulfil the leading role in Sponge City, urban planners are expected to step out of their comfort zones, and pay more attention to the integration with other disciplines and departments, the integration of social, cultural, and technical factors, and the balance the global strategies and local contexts. In the interviews, actors offered their opinions on what they believe urban planners are expected to achieve or the role that they hope they can fulfil. While all the actors have identified that planning should play a 'leading role' as explained above, some pointed out the importance for urban planners to also play an 'integrating role'. Regarding the integration of disciplines and departments, the actors recognised that "[the plan] brings together planning bureau and experts from various institutes/bureaus (C6)", and "planning is to take into account the whole situation and provide overall consideration (C18)". However, some expressed that "we need to make the rules at the planning level because the top-down approach is the most powerful (C1)", and "in China, you must force them to do it, if you don't make it mandatory nobody would want to do it. The plan should require the collaboration of [multiple disciplines] (C16)". From here, it is possible to see the tension between a network configuration linked by urban planners, and a hierarchical configuration with planning at the top of the ladder. Due to the combination of needing urban planners to integrate different disciplines and departments, and the extant hierarchical, or top-down relationship between the actors, the task of urban planners become more challenging, since "if the design is not well done, whatever we do at the downstream could risk being overturned (C23)", and "[when] the sponge city plan is not stable... people find it difficult to agree on things (C20)".

All actors agree that *planning* is the first step as dictated by the project flow, so planners (other than people who have worked on the application for pilot status) are the first point of contact, in other words, this is one of the first ties to be formed as a city seeks to pursue the Sponge City². As a result, planners tend to work closely with the local government bureau that is in charge of the project, as well as the Sponge City bureaus for the Pilot cities. Actors in other stages of the project may or may not have a direct relationship with the plan makers, but they are all indirectly linked with planners via the documents they produced. However, a tie between planning and design may weaken for various reasons, as discussed in the relational dimension section.

Most actors stated that the plan (and related documents) is the "link between different areas of the project (C12)" and "the plan informs the network components (U8)", but the urban planning professionals may not have direct connection with those who are connected via the plan (and related documents). In addition, many actors speak of the top-down system in China, and the network hierarchy affects the role of urban planning assumes. Many actors mentioned the importance of having an appropriate plan because it can increase the connectedness of the network

² Or any other urban water infrastructure project that is similar to Sponge City, since similar project or initiatives have been in action since the Sponge City started, and some of them overlap in terms of their targeting problems.

if it is correctly done while decreasing the stability of the network if it is not well done. The action of planning and the document that is the plan can connect different professions and disciplines. Many actors pointed out the top-down characteristics of the network and its benefits. The description “top-down” is muttered frequently in the interviews. As shown in the previous section, many people believed in the power of authority in improving communication, and a good plan seems to be an excellent tool to establish the hierarchy. However, the network struggles to form the hierarchy or the connections when the plan is not meeting the expectation of the project, or when there are changes that need to be made to deviate from the plan due to various reasons. From the interview excerpts, it is possible to see that there is a minimum flow of information from “downstream” professions to “upstream” planners.

6. Conclusions

China, as one of the major growing economics, is becoming a protagonist in the adoption and reformulation of sustainable development (41). The transition of urban water management requires a distinct shift in cognitive, regulative, and normative pillars of institutional practice, and changes to water management are underpinned by political and economic changes (19,35). Sponge City is China’s attempt to transition towards a more sustainable and resilient urban water management, which ultimately strengthens the public health of the society.

The urban water knowledge network contains vast amount of existing capacities and competencies to be tapped and shared (42). However, the discourse of tacit knowledge is infrequently found in the context of urban water management. From the semi-structured interviews conducted with Sponge City actors, examples of relational, somatic, and collective tacit knowledge were presented. The terrain of tacit knowledge was used to guide the analysis, which depicts relational as the “weakest”, somatic as the “weaker”, and collective as the “strongest” tacit knowledge. The collective tacit knowledge is the strongest and is tied to the culture and society’s unspoken rules, which is very relevant when we are comparing and adapting across cultural, historical, political boundaries. As all the Sponge City actors interviewed in this study are well situated in similar cultural context, the commonly identified type of tacit knowledge brought up were relational and somatic. While somatic tacit knowledge is limited by the capacity of the human body, relational tacit knowledge can be limited by a number of reasons. One common thread throughout is the potential of having urban planners as brokers of tacit knowledge.

Sustainable urban water management faces various challenges due to clashes in understanding, opinions and motivations that present difficulties in inter-disciplinary collaboration and communication. Additional layers of challenges are added because of the cultural and socio-political setting (38,43–45). Because of the strategic position occupied by the planning profession, and the diversity in their academic and professional backgrounds, urban planners have the potential to improve knowledge communication between different stages of projects and different professions.

This paper demonstrated the value of mapping different types of tacit knowledge as the basis for building stronger interdisciplinary collaboration to achieve sustainable urban water management. It also pointed to the different ways the tacitness of knowledge may influence the effectiveness of communication between water professionals. Having fulfilled the goal to distinguish the different types of tacit knowledge and identify examples in the Sponge City case, this will then enable the analysis of the access and mobilisation of different types of tacit knowledge identified. This study is therefore the first step in the investigation of the ways water professionals communicate across disciplines and fields in order to achieve sustainable urban water management.

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