PLOS WATER

RESEARCH ARTICLE

Professional perceptions of participatory practices in green stormwater infrastructure development

Mahsa Adib, Hong Wu*, Travis Flohr

Department of Landscape Architecture, The Pennsylvania State University, University Park, Pennsylvania, United States of America

* huw24@psu.edu

Abstract

Participatory practices are essential for green stormwater infrastructure (GSI) development that addresses stormwater issues while providing other ecosystem benefits. However, few studies have examined barriers to community engagement experienced by GSI professionals, particularly which phases include public participation, the groups they target, and the engagement mechanisms selected. If and how professionals evaluated their engagement processes or outcomes also remain under-investigated. This study fills these critical gaps through a survey (n = 195) and key informant interviews (n = 17) of professionals and academics previously involved in GSI development. We reveal that engagement initiatives for GSI are hindered mainly by available resources, knowledge and perceptions, requirements, and the COVID-19 Pandemic. Public hearings/information sessions and design workshops/charrettes are the most frequently applied engagement mechanisms, and current participation practices focus primarily on early project stages. While most of the reported benefits, challenges, and best practices are aligned with well-recognized general community engagement guides, GSI community engagement is uniquely challenged by project technical complexity and the need for effective knowledge transfer and long-term stewardship. Finally, the significant gap in engagement assessments calls for allocating adequate resources for evaluation and advancing research on appropriate evaluative methods based on project type, community context, and evaluation purpose.

Citation: Adib M, Wu H, Flohr T (2023) Professional perceptions of participatory practices in green stormwater infrastructure development. PLOS Water 2(3): e0000084. https://doi.org/10.1371/journal.pwat.0000084

Editor: Sara Marks, Eawag, SWITZERLAND

Received: August 29, 2022

Accepted: February 2, 2023

Published: March 1, 2023

Data Availability Statement: All research data has been submitted to the OPEN ICPSR repository at: https://www.openicpsr.org/openicpsr/project/178781/version/V1/view.

Funding: The author(s) received no specific external funding for this work.

Competing interests: The authors have declared that no competing interests exist.

1. Introduction

As climate change continues to cause global changes, such as rising sea levels and intense rainfall [1], stormwater management is becoming an increasing concern for communities of all sizes [2]. To address stormwater challenges, communities across the US are taking a step forward to integrate green stormwater infrastructure (GSI) into their stormwater management systems [3, 4]. GSI facilities, such as rain gardens and bioswales, use natural soil and vegetation processes to manage stormwater close to its source, thus restoring the hydrological and ecological functions of the urban landscape [5]. When planned and designed effectively, these

facilities have been demonstrated to provide multiple co-benefits beyond hydrological functions alone, such as heat island mitigation [6], habitat creation [7], public education [8], aesthetic value [9], and recreation [10]. The potential for widespread GSI facilities to serve as an urban regeneration catalyst with multiple social and economic co-benefits is increasingly acknowledged, especially in the context of future climate uncertainty [11–13].

Despite their benefits and potential to promote climate resiliency, GSI faces many implementation barriers, including those related to federal and city policies, governance, resources, and social perception [12, 14–17]. Social and cognitive factors are among the most critical barriers [18]. These barriers are primarily rooted in the public's negative mindset and attitudes toward GSI, their lack of knowledge about green and gray infrastructure benefits and challenges, their perceived risk on cost and performance of GSI practices, and their reluctance to accept maintenance responsibility [18]. In this context, Qi & Barclay [19] suggest that inadequate research on social and cognitive barriers may explain the delayed progress in GSI adoption to the necessary level for sustainable stormwater management and long-term capacity building.

The social and cognitive barriers could be best addressed through the engagement of the affected community [6]. In a broader context, GSI development offers an opportunity to understand the barriers and issues in community engagement for water management on private properties or in other small-scale neighborhood settings. Because of GSI's typical small size and decentralized nature, widespread adoption is critical for their benefits to emerge at the watershed scale [6, 9, 20, 21]. Many adoptions inevitably occur on privately held properties in urban areas. For instance, of the 1,073 acres of GSI completed in Philadelphia, US, by the end of 2017, 847 (79%) were on private properties. Besides initial adoption, constant maintenance for these decentralized GSI facilities also requires considerable community engagement and dedication. Therefore, examining participatory practices in GSI will inform the challenges and solutions toward developing a more collaborative decision-making process in urban water management. As current urban water problems become increasingly multi-scale, complex, and uncertain, shifting away from the previous predominately technocratic approach is critical to addressing the rising conflicts among different users and interests [22–24].

Whereas the literature on general community engagement is abundant, those specifically concerning GSI remain limited. Previous research has primarily focused on the significance and benefits of community engagement. For example, Barclay & Klotz [14] explored the role of community engagement in GSI development; Campbell-Arvai & Lindquist [25] identified the importance of community engagement for establishing GSI objectives; Groff [26] assessed the importance of community-engaged GSI in citywide sustainability. These studies affirm the advantages of community engagement in fostering inclusive GSI design, democratizing the design, boosting citizen trust, and facilitating two-way knowledge transfer of both the scientific aspects of the projects and the contextual background of the place [27].

There are several fundamental gaps in GSI-specific community engagement literature. First, few studies investigated the prevalence of community-engaged GSI projects in the first place, although many suggested that top-down decision-making remained the dominant approach [25]. Research concerning barriers primarily focused on those for GSI development in general rather than specifically for community engagement. Consequently, few studies synthesized the obstacles preventing engagement from occurring at the outset. Identifying strategies to overcome the potentially low occurrence of community-engaged GSI may be critical to addressing the social and cognitive barriers from the root of the problem.

Second, the current community engagement literature lacks evidence-based guidance specific to GSI development. Investigations of the target audiences, engagement phases, and

types of engagement methods remain lacking. In particular, guidance on the advantages, challenges, and best practices of engagement methods for GSI is absent. Although general community engagement guidelines are widely available, such as those by the US Environmental Protection Agency [28] and Community Places [29], they do not explicitly target the unique features of GSI projects. They also appear to be experience-informed rather than evidence-based, as they do not clearly indicate how the suggested best practices were derived.

Third, there is an increasing call for research that evaluates the community engagement process or outcomes in water management in general to identify best practices and promote accountability [30, 31]. Currently, similar research occurs primarily within the field of public health [32–34]. However, empirical assessments in water management remain very limited, let alone studies explicitly assessing community-engaged GSI projects. Thus, we are left wondering if the overall process or specific engagement mechanisms produced the intended outcomes. Furthermore, only a few studies have integrated specific evaluative criteria related to the process, outcomes, and context as recommended in the literature [35]. For example, Coore [36] used residents' attitudinal and behavioral change to evaluate the effectiveness of education in the form of a design charrette and brochures, reporting that the educational methods tested were largely ineffective in shifting attitudes and behaviors. More studies that apply scientifically rigorous measures to assess process-, outcome-, and context-related indicators are needed to inform ways to improve GSI engagement.

This study addresses the above three fundamental research gaps by exploring the perspectives of planning and design professionals previously involved in community-engaged GSI projects. We specifically investigate the following four research questions:

- RQ1: What are the professionals' perceived barriers to initiating community engagement for GSI development?
- RQ2: How have professionals applied existing community engagement mechanisms for GSI development concerning types, target populations, and phases?
- RQ3: What are the benefits, challenges, and best practices associated with each type of community engagement mechanism for GSI development?
- RQ4: How have community engagement outcomes been evaluated, and what are the evaluation outcomes?

2. Materials and methods

We applied mixed-methods research (Fig 1), integrating an online survey (June 2020 to February 2021) and key informant interviews (January–February 2021) of planning and design professionals with experience in community-engaged GSI development [37]. The survey and interviews complemented each other in collecting both quantitative (for RQ2 and RQ4) and qualitative data (for RQs 1–4). We first adopted the survey method because it offers an efficient and inexpensive means of gathering a large amount of information from a target population (i.e., GSI professionals) and exploring the general trends as well as underlying reasons [38]. However, because the survey was administered during the COVID-19 Pandemic and preliminary analysis in late 2020 revealed the need to collect more in-depth insight into how the Pandemic affected community engagement (RQ1), we added follow-up key informant interviews [39] in early 2021 as an adjustment to the research methods to investigate specific Pandemic-related barriers. No incentives were provided to the survey or interview participants.

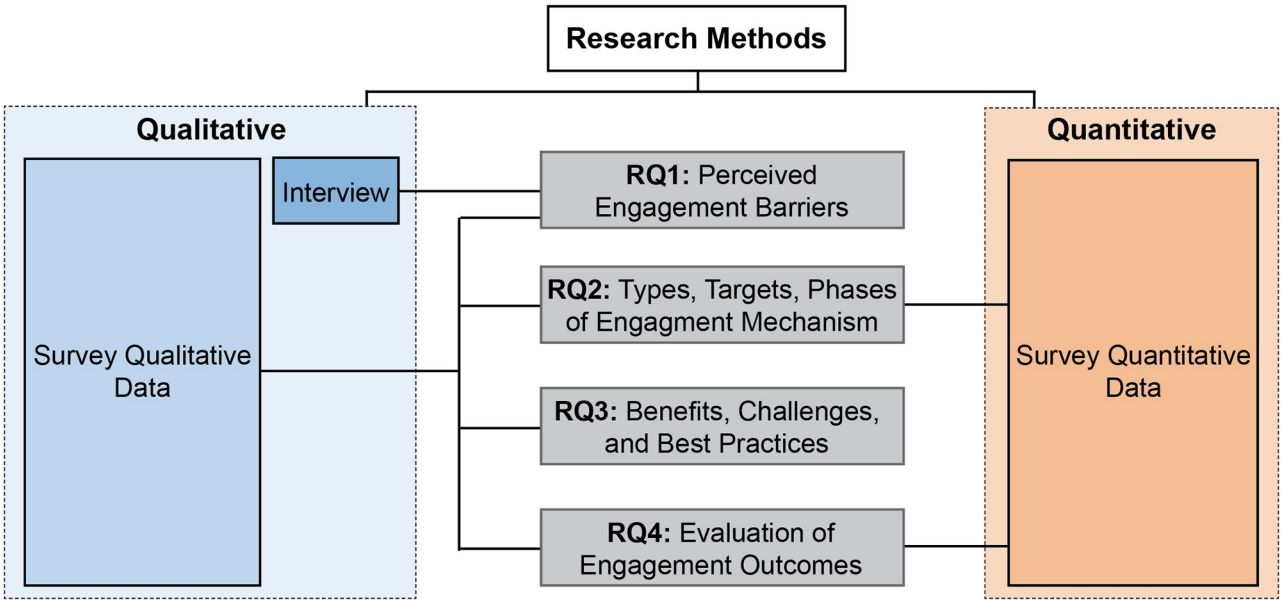

Fig 1. Mixed-methods study framework showing how quantitative and qualitative methods address respective research questions.

https://doi.org/10.1371/journal.pwat.0000084.g001

2.1. Ethics statement

Ethical clearance for the research was obtained from Penn State University's Institutional Review Board. The study (protocol 00014929) was deemed exempt. The online survey consent was granted by voluntary survey completion. Verbal informed consent was collected from all informants prior to the beginning of the interviews.

2.2. Survey and interview protocols

The online survey was administered through the Qualtrics platform. We utilized the stratified and snowball sampling methods [40] to recruit both public and private sector planning and design professionals previously involved in GSI projects on a national scale. For the stratified sampling specifically, we used the American Society of Landscape Architects (ASLA) National Firm Finder Tool to identify firms within 50 miles of the largest city in every state. Here, proximity to city centers was used as a proxy to capture firms more likely to have adequate resources to conduct community engagement. An email list with 547 contacts was compiled for survey distribution. The survey link was also published in several States' ASLA newsletters, EPA's NPSINFO Listserv (NPS stands for Nonpoint Source), and the Chesapeake Bay Program Newsletter. Additionally, because referrals will supplement the initial sampling strategies to augment the sample size, we broadened our sampling frame by asking participants to help forward the survey link to people familiar or experienced with community-engaged GSI initiatives. To estimate the appropriate sample size, we used Qualtrics' embedded "sample size calculator" tool [41] and obtained a suggested sample size of 187 based on an estimated population size of 600, 90% confidence level, and 5% margin of error. As a result, we concluded the survey in February 2021 after exhausting our research resources and confirming the ~200 samples received were of sufficient quantity and quality.

The survey instrument included four blocks of questions that corresponded with the four research questions. First, respondents who had not been involved in any community-engaged GSI projects were asked to elaborate on significant barriers (RQ1) in an open-ended question.

Second, participants with previous experience were asked to provide information via multiple-choice questions on a project they had been significantly involved in regarding types of applied community engagement mechanisms, associated project phases, and targeted populations (RQ2). Third, participants were asked to specify a mechanism they found either most effective or challenging and provide inputs for its benefits, challenges, and best practices via three open-ended questions (RQ3). Fourth, for RQ4, participants were asked to specify whether any evaluation on engagement outcomes was conducted, the timing of the evaluation, and the intended and self-evaluated achieved level of engagement, i.e., inform, involve, consult, collaborate, and empower based on Arnstein's Ladder of citizen participation [42]. Additionally, they were asked to specify the evaluative measures (i.e., methods used for evaluation such as surveys or interviews of engagement participants) and indicators for success (e.g., participation rate, project's degree of completion) [35] using multiple-choice and open-ended questions. Finally, through a series of 8-point Likert-scale questions (1 = strongly disagree, 7 = strongly agree, and 8 = unsure), participants indicated their level of agreement with whether their mechanism selections reflected core community engagement principles and values. These included whether the mechanisms were appropriate for the project type (i.e., appropriateness), kept the community involved throughout the process (i.e., involvement) [43], suited community context well (i.e., context), collected critical local knowledge (i.e., knowledge), provided co-learning opportunities for both community and professionals (i.e., co-learning), and built a strong stakeholder relationship for long-term collaboration (i.e., relationship) [14, 44, 45].

For the key informant interviews, we contacted the survey subjects who expressed willingness to participate in follow-up studies and used the snowball sampling method to recruit more participants. Seventeen interviews that lasted 45 minutes on average were conducted over Zoom meetings from January to February 2021. During the sessions, the interviewees first introduced their background and experience in community-engaged GSI projects and then provided insights on the barriers to effective community engagement during the COVID-19 Pandemic. The Zoom interviews were not recorded. Prior to the interviews, a series of questions were prepared based on the survey results and the background and expertise of the interviewee. The interviewer kept records of the responses using the note-taking technique [39] during and post-interviews.

2.3. Data analysis

We conducted all data analyses in Microsoft Excel and IBM SPSS. First, descriptive statistics and group comparison tests were employed for the quantitative survey data to identify patterns in the data and address specific research questions. In particular, the Wilcoxon Signed Ranks test [46], i.e., the non-parametric equivalent to the paired-samples t-test, was used to compare participants' intended and achieved levels of engagement (RQ4). The Friedman test [47], a non-parametric repeated measures ANOVA test, was employed to compare the six evaluative criteria (i.e., appropriateness, context, knowledge, co-learning, relationship, and involvement) for participants' applied mechanisms (RQ4).

Second, thematic analysis [48, 49] was used to analyze the qualitative data from the open-ended survey questions and interviews, primarily for the questions of GSI community engagement barriers and benefits, challenges, and best practices concerning specific engagement mechanisms. The general analysis process included: 1) two coders collaborated to familiarize themselves with the data by transcribing, reading, and rereading the data and noting down initial ideas; 2) initial codes were then generated by systematically color-coding data features across the entire dataset and collating data relevant to each code; 3) the codes were combined into potential themes and checked if the themes worked in relation to the coded extracts. The

definitions and names for each theme were continuously refined throughout the coding process; 4) coders analyzed the selected extracts and related them to the research questions and literature to inform primary findings and implications. More specifically, for GSI engagement barriers, we developed an additional diagram to illustrate relationships among barriers through deductive coding [50]. Regarding best practices of engagement mechanisms, because the respondents also offered insights on success lessons in general, we extracted those and summarized them into six success lessons. Finally, to situate our findings of the benefits, challenges, and best practices of each engagement mechanism within the broader literature, we compared them with 21 internationally recognized guidelines developed for effective community engagement both in stormwater management and beyond (S1 Table) and identified unique best practices from our study.

3. Results and discussion

A total of 195 survey responses from over 27 states (S2 Table) were collected. Participants belong to a variety of organizations, including private landscape architecture and multi-disciplinary firms (58%), local governments or other public sectors (32%), and academic organizations (10%). The size of the organizations varied from six to over 100 employees. A total of 147 respondents (75%) had participated in community-engaged GSI projects, while 48 (25%) had not. The former worked on GSI projects of various scales, including 41% at the community scale (e.g., green streets, community parks), 37% at the site scale (e.g., rain gardens, green roofs), and 22% at the watershed scale (e.g., series of BMPs throughout the watershed such as riparian buffers and constructed wetlands). The 17 interviewees also belong to a variety of organizations (S3 Table), including private firms (n = 10), government agencies and non-profit organizations (n = 5), and academic institutions (n = 2).

3.1 Perceived barriers to community-engaged GSI

Results for perceived community engagement barriers were derived from both open-ended survey responses and interviews. First, 45 open-ended responses were received from the 48 survey participants with no prior GSI community engagement experience. Sixty-three percent of the 48 participants indicated intention or initial efforts to engage the community but could not due to various barriers. Four major categories of perceived barriers emerged from the thematic analysis (Table 1), including resources (mentioned by 52% of participants), knowledge and perception (46%), requirements (40%), and the COVID-19 Pandemic (19%). The resource and knowledge and perception categories showed some overlap with the COVID-19 Pandemic category, especially in terms of funding and time constraints and professionals' lack of knowledge of effective online engagement mechanisms. Within each category, the most frequently mentioned subtypes are budget shortage, professionals' lack of knowledge of effective engagement mechanisms, absence of requirements/incentives, and pandemic health and safety protocols, respectively.

Second, the follow-up interview indicated five major types of barriers explicitly related to COVID-19 (Table 1). Communities' unfamiliarity with and limited access to new modes of engagement and available time, budget, and staff resources were more frequently mentioned than infrastructure capability to support new modes of engagement and the capabilities of available tools.

The diagram developed through deductive coding illustrated the ranking of the perceived barriers and their relationships (Fig 2). Overall, the lack of requirements and resource constraints (e.g., budget, time) appear to be foundational factors influencing the knowledge and perceptions of clients, professionals, and the public. More specifically, the public's lack of

Table 1. Barriers to community engagement perceived by the survey participants and interviewees.

Primary categories of barriers	Frequency of being mentioned	Type of barriers	Frequency of being mentioned
Survey (n = 48)			Count
Resource	52%	Lack of funding (1 clearly COVID-19-related)	17
		Lack of time investment (2 clearly COVID-19-related)	9
Knowledge and Perception	46%	Professionals' lack of knowledge of effective engagement mechanisms (4 clearly COVID-19-related)	9
		Clients' lack of knowledge about community engagement benefits	4
		Clients' lack of interest in community engagement	2
		Public's lack of knowledge about GSI benefits	8
		Public's lack of interest in community engagement	1
Requirement	40%	Not required by the client	7
		Lack of regulations/incentives	7
		Out of project scope (for unspecified reasons)	5
COVID-19 Pandemic	19%	Health and safety protocols	9
		Professionals' lack of knowledge of effective engagement mechanisms	4
Interviews (n = 17)			Count
COVID-19 Pandemic		Communities' unfamiliarity with and limited access to new modes of engagement	10
		Available time, budget, and staff resources	9
		Professionals' expertise and familiarity with new modes of engagement	7
		Organizational infrastructure to support new modes of engagement	5
		Capabilities of available tools	4

https://doi.org/10.1371/journal.pwat.0000084.t001

knowledge of GSI benefits and the clients'/professionals' lack of knowledge of community engagement benefits contributed to their lack of interest in community engagement. In addition, the professionals' lack of knowledge of effective engagement mechanisms also inhibited engagement, which was exacerbated by the COVID-19 Pandemic.

The findings of perceived barriers offer four major implications. First, the lack of regulations and incentives in public engagement, as a potential root cause of resources, knowledge, and perception limitations, needs to be addressed [51]. Stormwater regulations in the US associated with the Clean Water Act are administered under USEPA's MS4 (Municipal Separate Storm Sewer Systems) Program at the permit instead of project level. However, EPA [52] recently reviewed the final individual and general MS4 permits issued through August 2021 and did not find "Public Participation and Involvement," one of the six minimum control measures, to be a common requirement of reviewed permits, although "Public Education and Outreach" was commonly required. Furthermore, of the seven states that included the "Public Participation and Involvement" requirement, a majority only specify the minimum number (1–5) of involvement activities required for compliance [52]. Therefore, the extent and quality of public engagement in MS4 programs need improvement. To do so, the permits need to specify more details on, for example, the types of projects requiring engagement, procedures to ensure adequate resource allocation, incentives for developers, and reporting standards.

Second, ensuring allocating adequate funds and time to community engagement in the planning phase is essential to address the fundamental resource challenge [53]. The result that limited funding and time were the most frequently cited barriers (52%) by our survey participants echoes previous findings [14, 54]. Project budgets and schedules often cannot accommodate the substantial funds and time needed for sustaining participation in multiple project stages, which is critical for developing relationships, building trust, and strengthening

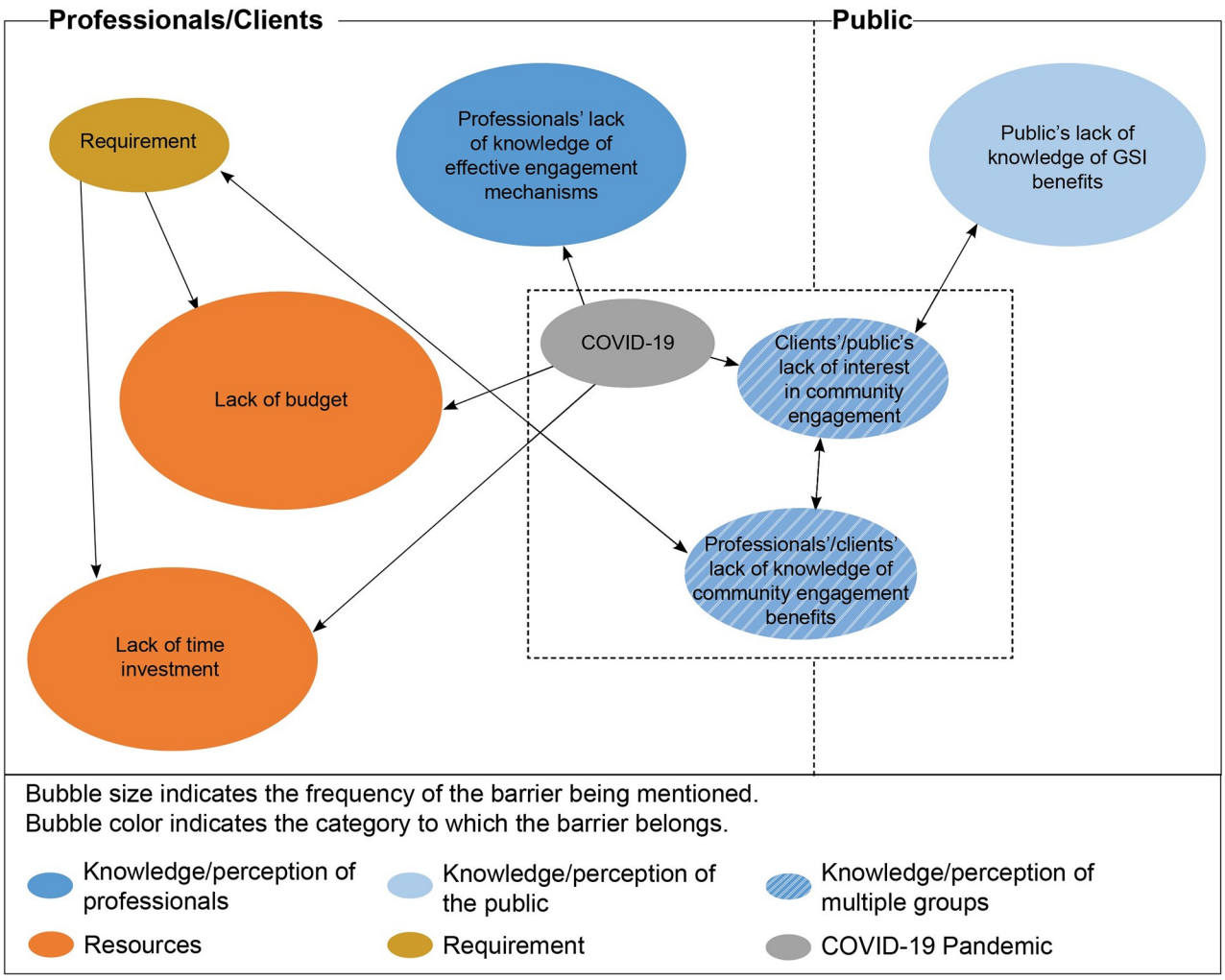

Fig 2. Barriers to initiating community engagement in GSI development.

https://doi.org/10.1371/journal.pwat.0000084.g002

collaborations. Therefore, adopting appropriate regulations and incentives and educating decision-makers about the necessity and benefits of community engagement will be essential to increase resource allocation at the onset of the project. In addition, distinguishing needed vs. desired engagement activities for each phase when developing the engagement plan can help ensure a basic budget is allocated for essential activities [53].

Third, the frequently mentioned knowledge and perception challenges align with the abundant literature that characterizes perceptual and cognitive barriers as one of the most significant obstacles to GSI implementation [18, 19]. The two top barriers reported here, i.e., the professionals' lack of knowledge of effective engagement mechanisms and the perceived inadequate public understanding of GSI benefits, emphasize the importance of best practice guidelines and training for professionals and broader and more effective science communication for the public [14, 55].

Fourth, the explicit COVID-19-related challenges, namely time, budget, staff limitations, and communities' unfamiliarity with and limited access to new modes of engagement, reveal the need to increase future resilience to resource shortages and develop a hybrid community

engagement framework integrating traditional in-person and web-based engagement methods. Additionally, enhancing the capabilities and availability of tools and ensuring adequate infrastructure to support new modes of engagement will help sustain meaningful community engagement in the face of future pandemics [56, 57].

3.2. Types, targets, and phases of engagement mechanisms

3.2.1. Engagement mechanism types. The survey participants reported seven major types of engagement mechanisms (Fig 3A), including public hearing/information session, design workshop/charrette, focus group, interview, online mapping, survey, and community events (listed from the most to least frequently cited). Other mechanisms included online engagement through social media, websites and newsletters, targeted mailers, banners, and site signage. A majority (76%) of the respondents used multiple mechanisms during the single project they chose to discuss, while 24% used a single mechanism. The mechanisms' ability to reach different audiences, client requirements or regulations, available resources (e.g., budget, staff, and time), and ease of use were listed as primary reasons for mechanism selection in participants' open-ended responses.

3.2.2. Targeted populations and role of community. Next, regarding the targeted populations, existing GSI programs try to involve a broad spectrum of stakeholders, including local elected officials, government planners, special interest groups/NGOs, and citizen individuals and groups (Fig 3B). As expected, citizen individuals and groups were the most common targets of all engagement mechanisms except for online mapping, for which local government planners were the primary targets. Local elected officials were the least frequently mentioned target than the other groups, except during public hearings/information sessions where special interest groups/NGOs were the least involved. While our study began to identify major audiences and related phases, future work should continue to assess the need to broaden the stakeholder network as well as gaps in community representation [58].

Regarding roles of the community, 116 open-ended responses were received and categorized into four major types: visioning and providing initial input during various project phases (64%), consulting and providing feedback for conceptual design, design review, final design, and implementation (44%), participating in construction and maintenance (16%), educating other community members as champions and serving as long-term stewards (10%).

3.2.3. Mechanisms for various phases. Regarding project phases, the majority (69%) of respondents engaged the community during multiple phases (Fig 3C). However, current practices mostly focused on the two early phases, i.e., planning and decision-making (73%) and conceptual design (54%). Design development (26%), construction (23%), and maintenance (24%) had similar lower frequencies (Fig 3D). A very low percentage (9%) of projects maintained engagement for four or all five phases, consistent with previous findings [59].

The application frequencies of various engagement mechanisms showed distinguishing patterns for different phases (Fig 3E). For example, mechanisms were applied relatively equally for planning and design development (e.g., 20–21% for three mechanisms in the design development phase). In contrast, community events and training sessions (30%) were the predominant modes of engagement for the construction and maintenance phases.

Overall, the above results about the most applied mechanisms (public hearings/information sessions and design workshops/charrettes), the community's primary roles (envisioning ideas and providing input/feedback), and most underserved project phases (construction and maintenance) underscore the need to extend engagement into the construction and maintenance phases while fostering the community's role as long-term stewards [60]. Keeping the

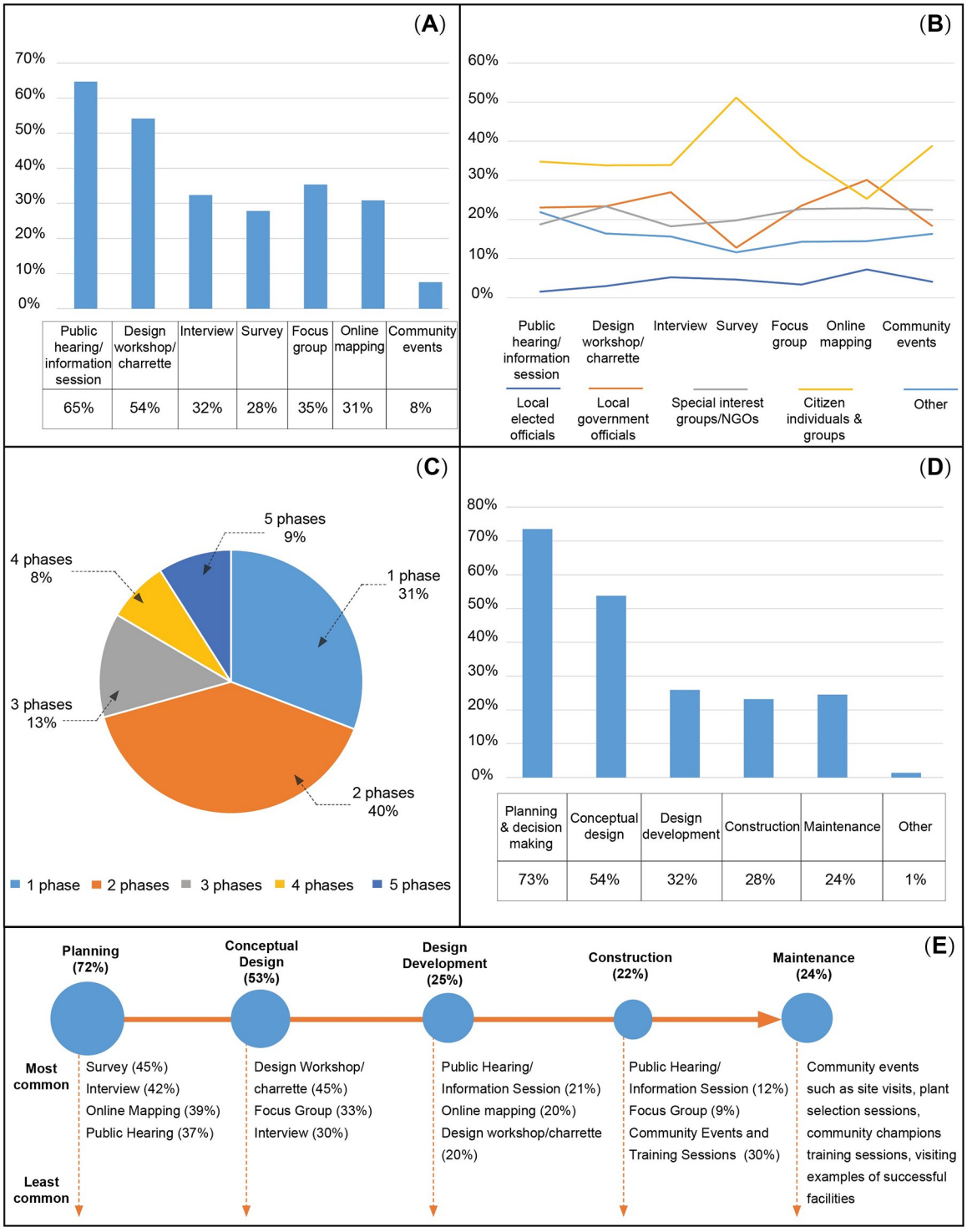

Fig 3. Types (A), targets (B), and phases (C-E) of engagement mechanisms.

https://doi.org/10.1371/journal.pwat.0000084.g003

community engaged during construction and maintenance helps them understand how GSI functions and what maintenance activities are required to sustain facility performance, meanwhile helping to avoid construction and maintenance errors that can severely compromise long-term performance and community acceptance [61]. Such engagement also encourages community members to voluntarily contribute to maintenance and become dedicated stewards of those projects.

3.3. Benefits, challenges, and best practices

Next, we gathered open-ended survey responses about the mechanisms' benefits (115), challenges (66), and best practices (65). They were organized into seven categories: inclusivity, interactivity/transparency, quality of input, knowledge transfer effectiveness, cost/time effectiveness, flexibility, and influence (see examples in Fig 4 and the full summary in S5 Table). These categories were drawn from the community engagement core values and principles suggested by the International Association for Public Participation [62]. The most frequently mentioned benefits were related to the quality of input, followed by knowledge transfer and cost/time effectiveness, indicating that respondents may have prioritized these criteria to select

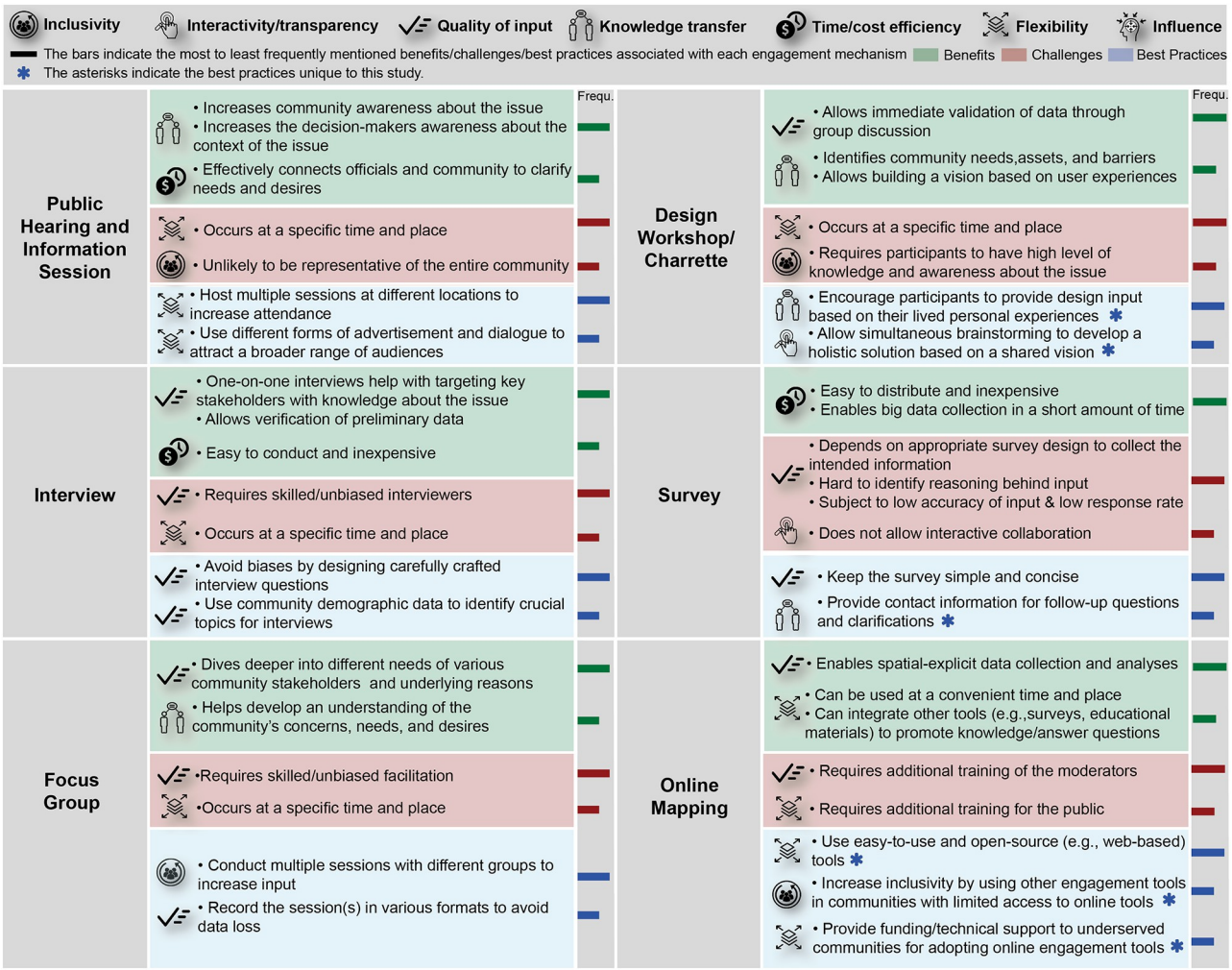

Fig 4. Examples of benefits, challenges, and best practices of each engagement mechanism.

https://doi.org/10.1371/journal.pwat.0000084.g004

mechanisms that can effectively and accurately capture community needs [14, 42] and foster education on the topic [63]. In contrast, the most frequently mentioned challenges were related to flexibility, inclusivity, and interactivity/transparency, while the most frequently mentioned best practices addressed two of the same categories—flexibility and inclusivity, in addition to input quality (Fig 4). Although some of the recommended best practices began to address the challenges listed, additional research would be necessary to tackle the remaining gaps within resource and time constraints.

While most of the above findings align with recommendations from the 21 community engagement guidelines mentioned above, six unique best practices emerged (see asterisks in Fig 4); three out of six were for online mapping. These unique best practices emphasize the importance of actively seeking transparent interaction and knowledge transfer among diverse populations. The three best practices for online mapping begin to fill the gap in integrating online with traditional in-person engagement tools. However, more studies are required to address the lack of guidelines on hybrid engagement.

Besides specific best practices for each mechanism, six general success lessons also emerged, including 1) performing and presenting analyses to quantify the projects' stormwater issues; 2) engaging city regulatory review staff and approval agencies in the early design stage; 3) hands-on design activities such as breaking down precedent projects by components and allowing community members to select individual elements; 4) keeping the community engaged during installation; 5) conducting maintenance training sessions and funding multi-year follow-up tasks to keep the community involved in maintenance; 6) promoting the project in the entire community to raise awareness of GSI benefits and broaden GSI implementation in other areas of the community.

These success lessons highlight several qualities suggested by literature as critical to GSI development: specifically addressing technical complexity, enhancing knowledge transfer, and supporting long-term stewardship [19, 60]. More specifically, GSI projects' technical complexity underscores the importance of showing (e.g., via site runoff calculation demonstrations) instead of telling the community how stormwater issues can be addressed explicitly in their neighborhoods. Additionally, engaging regulatory agencies early on will help avoid unnecessary design revisions and facilitate approval. Furthermore, as mentioned before, hands-on design activities, engagement during construction, and maintenance training sessions are effective knowledge transfer strategies that make the structure and operation of the systems comprehensible and encourage long-term stewardship. Last but not least, continuous efforts to promote the project within and beyond the community where the project is installed are essential for sustaining public support.

3.4. Evaluation of engagement outcomes

First, a majority (68%) of the 121 participants who responded about the evaluation of engagement outcomes did not conduct any formal assessment. In contrast, 14% conducted evaluation throughout the engagement process and 18% upon project completion (Fig 5A). Seven types of evaluative measures were mentioned (Fig 5B). Self-evaluation by observation and documentation and survey of engagement participants were the most frequently applied measures. Additionally, four primary categories of assessment indicators were reported (Fig 5C). Amount and/or quality of community feedback on the engagement process and sustained engagement/strengthened relationship were mentioned more than the other two, i.e., project progress (with respect to the degree of completion, facility performance, or funding status), and participation rate and representativeness of the community (Fig 5C).

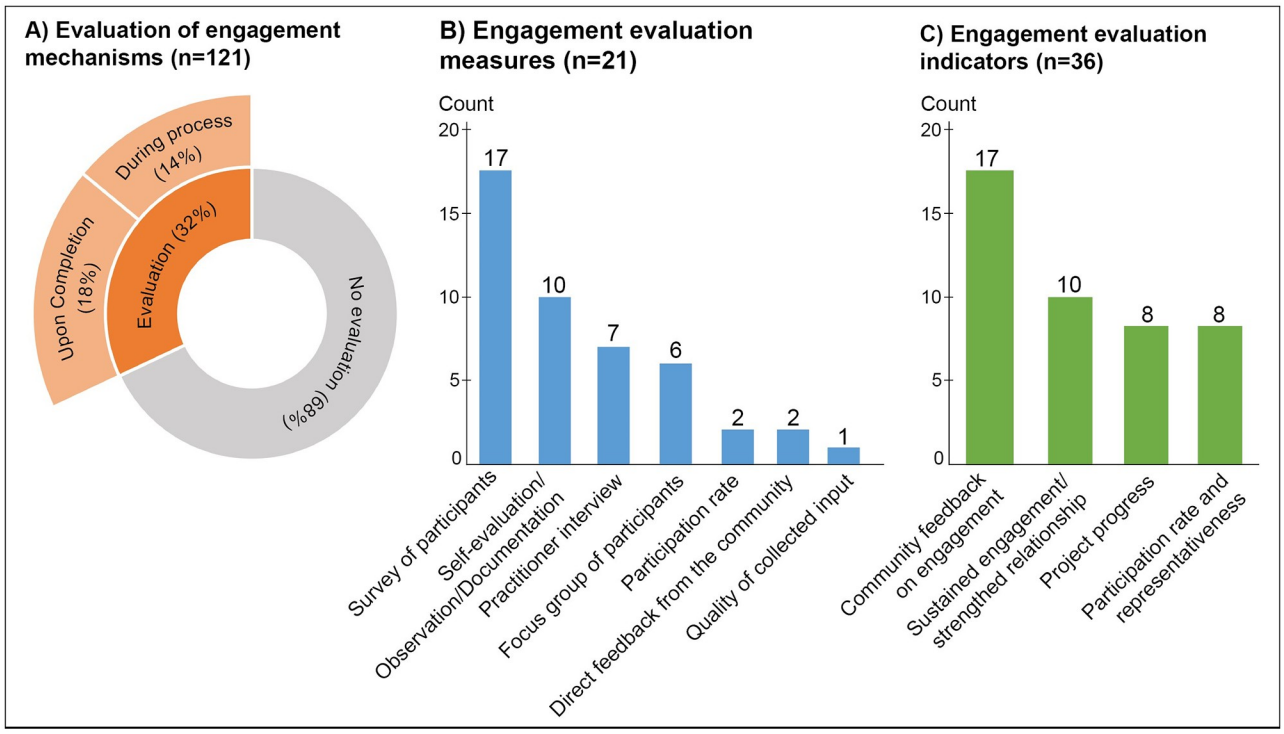

Fig 5. Evaluation of engagement outcomes: (A) percentage projects with or without evaluation; (B) evaluation measures; (C) evaluation indicators.

https://doi.org/10.1371/journal.pwat.0000084.g005

The low occurrence (32%) of engagement evaluation echoes existing literature [35, 64] and calls for actions to address this critical gap so that we continue to learn from past successes and failures. Although respondents used some evaluation indicators suggested by the literature, e.g., sustained engagement/strengthened relationship, participation rate and representativeness, and project progress [35, 64], they mostly relied on a small number of metrics and self-assessment without involving a more neutral party. The demand for additional resources to be allocated up front and lack of knowledge about effective evaluation frameworks and methods may be the primary reasons evaluation has been neglected in practice.

Adequate funding, staff, and time should be allocated, and regulatory requirements considered to advance engagement evaluation. Because no standardized evaluation approach exists, researcher-practitioner collaborations should be encouraged to inform the selection of appropriate measures and indicators based on the purposes of the evaluation, project type, and community characteristics. Incentives and platforms should be provided to encourage sharing of evaluative results so that professionals can gain advanced and evidence-based knowledge of successes and failures.

Second, the participants' assessments of applied mechanisms showed significant differences among the six criteria of appropriateness, context, knowledge, co-learning, relationship, and involvement, $\chi^2(5, N = 121) = 54.70$, ($p < 0.001$) (Fig 6). Post-hoc pairwise comparisons with Bonferroni correction revealed significant differences for the pairs of appropriateness vs. involvement/relationship/co-learning and context vs. involvement (Fig 6, see detailed statistics in S4 Table). Participants thought that their selected mechanisms performed the best in fitting the project type (appropriateness) and community context (context), but fell short, in general, in keeping the community involved throughout the process (involvement), building strong,

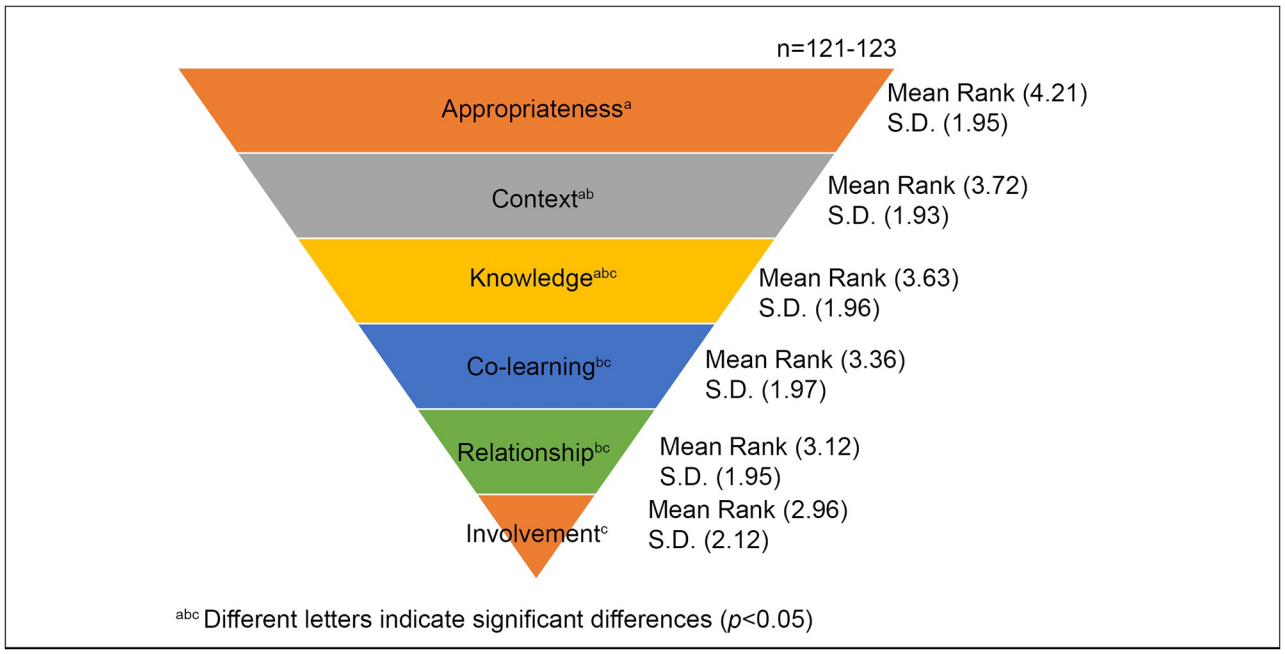

Fig 6. Participants' assessment of applied mechanisms.

https://doi.org/10.1371/journal.pwat.0000084.g006

long-term relationships (relationship), and providing co-learning opportunities (co-learning). The best practices and success lessons discussed in the section above can help address these shortcomings. Still, future research should continue to tackle these challenges, developing more specific guidelines for best practices.

Lastly, regarding average levels of engagement, both the intended and achieved levels fell between *involve* and *collaborate* (means are 3.74 and 3.96, respectively), with no significant difference as revealed by the Wilcoxon Signed Ranks test ($p = 0.53$). This underscores the real-world difficulty in achieving the highest level of engagement—civic *empowerment*. Besides improving engagement mechanisms, stronger implementation procedures and enforcement mechanisms (e.g., mandatory public hearings before major design decisions) will likely be necessary to ensure that community priorities are reflected in decision-making at all project stages.

3.5. Contributions and future directions

The primary contributions of this work include a synthesis of the types of barriers to initiating community engagement in GSI projects, a comprehensive characterization of the phases, target populations, and commonly applied mechanisms for GSI engagement, as well as an examination of the ways in which professionals have evaluated their engagement efforts and their perceived level of achievement. Specifically, the findings on the relationships of the perceived barriers (Fig 2) offer important implications for addressing the root causes of community engagement challenges. Additionally, the summary of the benefits, challenges, and best practices of the various mechanisms revealed both overlapping and unique recommendations compared to the 21 community engagement manuals and guidelines we reviewed. Although not exhaustive, our compilation contributes to the creation of GSI-specific guidelines through empirical research. Future work can delve deeper into developing a comprehensive GSI engagement guideline, especially for the most underserved construction and maintenance

phases. Lastly, the limited occurrence and low quality of engagement evaluation and the perceived difficulty in achieving civic empowerment call for more researcher-practitioner collaborations and supporting resources so that civic participation can truly serve as an instrument for ecological, social, and institutional change [24].

Despite these critical contributions, we note several limitations of the study and future research directions. First, the COVID-19 Pandemic may have impacted this study in multiple ways, including sample size and research outcomes. The relatively small survey sample size may be attributed to overloaded online communications and other general life challenges under a global pandemic. The study results, particularly those related to barriers and online engagement mechanisms, were also affected. On the other hand, the findings revealed that many public and private organizations remained in the early stage of experimenting with web-based engagement tools. Therefore, timely research into these tools and technologies will be valuable to assess their effectiveness and help realize their full potential in the face of future uncertainties. Second, this study focused on the viewpoints of governmental officials, private practitioners, and university academics. Perceptions of other stakeholder groups, such as community members previously engaged in GSI projects, would be essential to include in future work. Additionally, comparisons of perspectives of the public and practitioners will be valuable to inform differences in community engagement obstacles, facilitators, and outcomes. Lastly, the small sample size also limited our ability to tease out nuanced differences in community engagement practices by project scale (i.e., site vs. neighborhood vs. watershed), type (i.e., public vs. private vs. mixed), or region. Future work could continue to tackle these nuanced differences to provide more context-specific guidance.

4. Conclusions

Through online surveys and key informant interviews, we explored the barriers to community engagement for GSI, identified the types, targets, and phases of the applied engagement mechanisms, synthesized the mechanisms' benefits, challenges, and best practices, and examined the evaluation process of engagement outcomes. We found that, first, resources, knowledge and perceptions, requirements, and COVID-19 Pandemic were the predominant barriers to initiating GSI community engagement (RQ1). Addressing the lack of requirements/incentives, ensuring resources are allocated for engagement at the planning stage, increasing training for professionals on effective mechanisms and processes, and educating clients for engagement benefits and the public for GSI benefits are all promising strategies to enhance future participatory practices. Second, with public hearings/information sessions and design workshops/charrettes being the two most frequently applied engagement mechanisms, current GSI community engagement primarily focused on early project stages (RQ2). Extending participation into the most underserved construction and maintenance phases will be critical to fostering the community's role as long-term stewards beyond helping to envision ideas and provide input or feedback. Third, most of the reported benefits, challenges, and best practices aligned with well-recognized national and international general community engagement guides (RQ3). However, GSI community engagement is also distinctively challenged by project technical complexity and the need for effective knowledge transfer and long-term stewardship, requiring additional GSI-specific guidelines such as the several developed in this study. Besides, more adaptive and inventive hybrid methods are essential to increasing preparedness for future pandemics. Finally, the significant gap in the engagement process and/or outcome evaluation indicates an urgent need to allocate adequate resources for assessment and facilitate researcher-practitioner collaborations to develop appropriate evaluative methods based on project type, community context, and evaluation purpose (RQ4).

GSI is an effective strategy for managing stormwater on-site while providing other ecological, social, and economic benefits. However, delivering these benefits at a larger scale in the face of climate change requires widespread adoption, collaboration, willingness to invest, a longer-term view of the return in benefits, and more robust policy support. Participatory practices are key to overcoming implementation barriers but, as demonstrated above, still face substantial challenges in resources (for carrying out both engagement and its evaluation), regulations and incentives (for ensuring participation), guidelines (for improving mechanisms and processes), and knowledge and perceptions (for facilitating effective collaborations among clients, professionals, and the public). Our work began to reveal the specifics of these challenges, their root causes, and solutions for GSI implementation while also providing broader research and practice implications for improving future water governance in general.

Many global cities are wrestling with increasingly challenging water management problems while adapting to climate change. The growing technical, social, and financial complexities in water infrastructure planning and design, deep uncertainty related to infrastructure vulnerability and performance under climate change, as well as the extensive impact of water infrastructure (especially dispersed GSI) on people's daily lives call for substantial investment, a long-term perspective, effective social learning, and a more collaborative decision-making process in water governance [65]. Planning ahead, reducing siloed approaches and supporting collaborative thinking, executing engagement activities utilizing effective methods and processes, maximizing the ability to assess engagement and learn from the past, and identifying creative ways to sustain engagement are key areas in need of improvement. It will be essential for social scientists and practitioners to work together to advance these areas for more accessible, inclusive, effective, and adaptive participatory practices that genuinely support building a sustainable future for the citizens.

Supporting information

S1 Table. Community engagement guidelines reviewed.
(DOCX)

S2 Table. Reported locations of survey participants (Note: Only 50.8% of the 195 respondents reported their locations).
(DOCX)

S3 Table. Key informant information.
(DOCX)

S4 Table. Post-hoc pairwise comparisons among the six criteria of appropriateness, context, knowledge, co-learning, relationship, and involvement. Only significant ($p < 0.05$) results are shown.
(DOCX)

S5 Table. Comprehensive list of benefits, challenges, and best practices.
(DOCX)

Acknowledgments

This research was supported by the Penn State Stormwater Living Lab and the Hamer Center for Community Design. The authors wish to thank Dr. Timothy Kelsey (Department of Agricultural Economics, Sociology, and education, Penn State) for his guidance in developing the survey instrument and the valuable discussions and comments about the research design. We

also thank all the survey participants and interviewees for providing their time and valuable knowledge.

Author Contributions

Conceptualization: Mahsa Adib, Hong Wu, Travis Flohr.

Data curation: Mahsa Adib.

Formal analysis: Mahsa Adib.

Investigation: Mahsa Adib.

Methodology: Mahsa Adib, Hong Wu, Travis Flohr.

Project administration: Hong Wu.

Resources: Hong Wu.

Supervision: Hong Wu.

Visualization: Mahsa Adib.

Writing – original draft: Mahsa Adib.

Writing – review & editing: Hong Wu, Travis Flohr.

References

1. Wang M, Zhang DQ, Su J, Trzcinski AP, Dong JW, Tan SK. Future Scenarios Modeling of Urban Stormwater Management Response to Impacts of Climate Change and Urbanization. Clean—Soil, Air, Water. 2017 Oct; 45(10):1700111.
2. Gao Y, Babin N, Turner AJ, Hoffa CR, Peel S, Prokopy LS. Understanding urban-suburban adoption and maintenance of rain barrels. Landscape and Urban Planning. 2016 Sep; 153:99–110.
3. Fitzgerald J, Laufer J. Governing green stormwater infrastructure: the Philadelphia experience. Local Environment. 2017 Feb; 22(2):256–68.
4. Newell JP, Seymour M, Yee T, Renteria J, Longcore T, Wolch JR, et al. Green Alley Programs: Planning for a sustainable urban infrastructure? Cities. 2013 Apr; 31:144–55.
5. Spahr KM, Smith JM, McCray JE, Hogue TS. Reading the Green Landscape: Public Attitudes toward Green Stormwater Infrastructure and the Perceived Nonmonetary Value of Its Co-Benefits in Three US Cities. J Sustainable Water Built Environ. 2021 Nov; 7(4):04021017.
6. Montalto FA, Bartrand TA, Waldman AM, Travaline KA, Loomis CH, McAfee C, et al. Decentralised green infrastructure: the importance of stakeholder behaviour in determining spatial and temporal outcomes. Structure and Infrastructure Engineering. 2013 Dec; 9(12):1187–205.
7. Jessup K, Parker SS, Randall JM, Cohen BS, Roderick-Jones R, Ganguly S, et al. Planting Stormwater Solutions: A methodology for siting nature-based solutions for pollution capture, habitat enhancement, and multiple health benefits. Urban Forestry & Urban Greening. 2021 Sep; 64:127300.
8. Meenar M, Howell J, Moulton D, Walsh S. Green Stormwater Infrastructure Planning in Urban Landscapes: Understanding Context, Appearance, Meaning, and Perception. Land. 2020 Dec 21; 9 (12):534.
9. Baptiste AK, Foley C, Smardon R. Understanding urban neighborhood differences in willingness to implement green infrastructure measures: a case study of Syracuse, NY. Landscape and Urban Planning. 2015 Apr; 136:1–12.
10. Demuzere M, Orru K, Heidrich O, Olazabal E, Geneletti D, Orru H, et al. Mitigating and adapting to climate change: Multi-functional and multi-scale assessment of green urban infrastructure. Journal of Environmental Management. 2014 Dec; 146:107–15. https://doi.org/10.1016/j.jenvman.2014.07.025 PMID: 25163601
11. Green Infrastructure and Climate Change Collaborating to Improve Community Resiliency.: 26.
12. Matthews T, Lo AY, Byrne JA. Reconceptualizing green infrastructure for climate change adaptation: Barriers to adoption and drivers for uptake by spatial planners. Landscape and Urban Planning. 2015 Jun; 138:155–63.

13. Shade C, Kremer P, Rockwell JS, Henderson KG. The effects of urban development and current green infrastructure policy on future climate change resilience. E&S. 2020; 25(4):art37.

14. Barclay N, Klotz L. Role of community participation for green stormwater infrastructure development. Journal of Environmental Management. 2019 Dec; 251:109620. https://doi.org/10.1016/j.jenvman.2019.109620 PMID: 31569019

15. Brown RR, Farrelly MA. Delivering sustainable urban water management: a review of the hurdles we face. Water Science and Technology. 2009 Mar 1; 59(5):839–46. https://doi.org/10.2166/wst.2009.028 PMID: 19273882

16. O'Donnell EC, Lamond JE, Thorne CR. Recognising barriers to implementation of Blue-Green Infrastructure: a Newcastle case study. Urban Water Journal. 2017 Oct 21; 14(9):964–71.

17. Roy AH, Wenger SJ, Fletcher TD, Walsh CJ, Ladson AR, Shuster WD, et al. Impediments and Solutions to Sustainable, Watershed-Scale Urban Stormwater Management: Lessons from Australia and the United States. Environmental Management. 2008 Aug; 42(2):344–59. https://doi.org/10.1007/s00267-008-9119-1 PMID: 18446406

18. Dhakal KP, Chevalier LR. Managing urban stormwater for urban sustainability: Barriers and policy solutions for green infrastructure application. Journal of Environmental Management. 2017 Dec; 203:171–81. https://doi.org/10.1016/j.jenvman.2017.07.065 PMID: 28783013

19. Qi J, Barclay N. Social Barriers and the Hiatus from Successful Green Stormwater Infrastructure Implementation across the US. Hydrology. 2021 Jan 15; 8(1):10.

20. Seo M, Jaber F, Srinivasan R, Jeong J. Evaluating the Impact of Low Impact Development (LID) Practices on Water Quantity and Quality under Different Development Designs Using SWAT. Water. 2017 Mar 7; 9(3):193.

21. Ureta J, Motallebi M, Scaroni AE, Lovelace S, Ureta JC. Understanding the public's behavior in adopting green stormwater infrastructure. Sustainable Cities and Society. 2021 Jun; 69:102815.

22. Roovers GJ, van Buuren MW. Stakeholder participation in long term planning of water infrastructure. Infrastruct Complex. 2016 Jan 20; 3(1):1.

23. Ruiz-Villaverde A, García-Rubio MA. Public Participation in European Water Management: from Theory to Practice. Water Resour Manage. 2017 Jun 1; 31(8):2479–95.

24. von Korff Y, Daniell KA, Moellenkamp S, Bots P, Bijlsma RM. Implementing Participatory Water Management: Recent Advances in Theory, Practice, and Evaluation. Ecology and Society [Internet]. 2012 [cited 2022 Nov 23]; 17(1). Available from: https://www.jstor.org/stable/26268987

25. Campbell-Arvai V, Lindquist M. From the ground up: Using structured community engagement to identify objectives for urban green infrastructure planning. Urban Forestry & Urban Greening. 2021 Apr; 59:127013.

26. Groff J. Stormwater management in Philadelphia: The importance of green stormwater infrastructure and community involvement in greater citywide sustainbility. 2018;149.

27. Shandas V, Messer WB. Fostering Green Communities Through Civic Engagement: Community-Based Environmental Stewardship in the Portland Area. Journal of the American Planning Association. 2008 Oct 21; 74(4):408–18.

28. Community Engagement Strategy [Internet]. US EPA. 2017. [cited 2023 Feb 6]. https://www.epa.gov/sites/default/files/2017-03/documents/tribalswcommunityengagementstrategy508.pdf

29. Community Engagement | Community Planning Toolkit [Internet]. [cited 2023 Feb 7]. https://www.communityplanningtoolkit.org/community-engagement

30. Rowe G, Frewer LJ. Evaluating Public-Participation Exercises: A Research Agenda. Science, Technology, & Human Values. 2004 Oct; 29(4):512–56.

31. van Buuren A, van Meerkerk I, Tortajada C. Understanding emergent participation practices in water governance. International Journal of Water Resources Development. 2019 May 4; 35(3):367–82.

32. Boivin A, L'Espérance A, Gauvin FP, Dumez V, Macaulay AC, Lehoux P, et al. Patient and public engagement in research and health system decision making: A systematic review of evaluation tools. Health Expectations. 2018; 21(6):1075–84. https://doi.org/10.1111/hex.12804 PMID: 30062858

33. Dukhanin V, Topazian R, DeCamp M. Metrics and Evaluation Tools for Patient Engagement in Healthcare Organization- and System-Level Decision-Making: A Systematic Review. Int J Health Policy Manag. 2018 May 16; 7(10):889–903. https://doi.org/10.15171/ijhpm.2018.43 PMID: 30316241

34. Hendricks S, Conrad N, Douglas TS, Mutsvangwa T. A modified stakeholder participation assessment framework for design thinking in health innovation. Healthcare. 2018 Sep; 6(3):191–6. https://doi.org/10.1016/j.hjdsi.2018.06.003 PMID: 29960878

35. Luyet V, Schlaepfer R, Parlange MB, Buttler A. A framework to implement Stakeholder participation in environmental projects. Journal of Environmental Management. 2012 Nov 30; 111:213–9. https://doi.org/10.1016/j.jenvman.2012.06.026 PMID: 22926750

36. Coore D. Evaluating the Effectiveness of Community Engagement Strategies for Shifting Attitudinal Behaviour Towards Green Stormwater Infrastructure. 2019;178.

37. Brannen J. Mixing Methods: The Entry of Qualitative and Quantitative Approaches into the Research Process. International Journal of Social Research Methodology. 2005 Jul; 8(3):173–84.

38. Gideon L, editor. Handbook of Survey Methodology for the Social Sciences [Internet]. New York, NY: Springer New York; 2012 [cited 2023 Jan 30]. https://link.springer.com/10.1007/978-1-4614-3876-2

39. Fox N. Using interviews in a research project. The NIHR RDS for the East Midlands/Yorkshire & the Humber. 2009;26.

40. Yadav SK, Singh S, Gupta R. Biomedical Statistics: A Beginner's Guide [Internet]. Singapore: Springer Singapore; 2019 [cited 2022 Nov 13]. https://link.springer.com/10.1007/978-981-32-9294-9

41. Smith SM. How to ensure you get the correct sample size [Internet]. 2020 [cited 2023 Feb 6]. https://www.qualtrics.com/experience-management/research/determine-sample-size/

42. Arnstein SR. A Ladder Of Citizen Participation. Journal of the American Institute of Planners. 1969 Jul; 35(4):216–24.

43. Rowe G, Frewer LJ. Public Participation Methods: A Framework for Evaluation. Science, Technology, & Human Values. 2000 Jan 1; 25(1):3–29.

44. Reed MS. Stakeholder participation for environmental management: A literature review. Biological Conservation. 2008 Oct 1; 141(10):2417–31.

45. Wehn U, Collins K, Anema K, Basco-Carrera L, Lerebours A. Stakeholder engagement in water governance as social learning: lessons from practice. Water International. 2018 Jan 2; 43(1):34–59.

46. Wilcoxon F. Individual Comparisons by Ranking Methods. Biometrics Bulletin. 1945; 1(6):80–3.

47. Friedman M. The Use of Ranks to Avoid the Assumption of Normality Implicit in the Analysis of Variance. Journal of the American Statistical Association. 1937 Dec 1; 32(200):675–701.

48. Braun V, Clarke V, Hayfield N, Terry G. Thematic Analysis. In: Liamputtong P, editor. Handbook of Research Methods in Health Social Sciences [Internet]. Singapore: Springer Singapore; 2018 [cited 2022 Jan 6]. p. 1–18. http://link.springer.com/10.1007/978-981-10-2779-6_103-1

49. Guest G, MacQueen K, Namey E. Applied Thematic Analysis [Internet]. 2455 Teller Road, Thousand Oaks California 91320 United States: SAGE Publications, Inc.; 2012 [cited 2022 Jan 6]. http://methods.sagepub.com/book/applied-thematic-analysis

50. Skjott Linneberg M, Korsgaard S. Coding qualitative data: a synthesis guiding the novice. QRJ. 2019 Jul 24; 19(3):259–70.

51. Lieberherr E, Green O. Green Infrastructure through Citizen Stormwater Management: Policy Instruments, Participation and Engagement. Sustainability. 2018 Jun 20; 10(6):2099.

52. US EPA O. Stormwater Phase II Final Rule Fact Sheet Series [Internet]. 2015 [cited 2023 Feb 6]. https://www.epa.gov/npdes/stormwater-phase-ii-final-rule-fact-sheet-series

53. Wilker J, Rusche K, Rymsa-Fitschen C. Improving Participation in Green Infrastructure Planning. Planning Practice & Research. 2016 May 26; 31(3):229–49.

54. Mostert E. The challenge of public participation. Water Policy. 2003 Apr; 5(2):179–97.

55. Green OO, Shuster WD, Rhea LK, Garmestani AS, Thurston HW. Identification and Induction of Human, Social, and Cultural Capitals through an Experimental Approach to Stormwater Management. Sustainability. 2012 Aug 6; 4(8):1669–82.

56. Marsh EE, Kappelman MD, Kost RG, Mudd-Martin G, Shannon J, Stark LA, et al. Community engagement during COVID: A field report from seven CTSAs. J Clin Trans Sci. 2021; 5(1):e104.

57. Fedorowicz M. Community Engagement during the COVID-19 Pandemic and Beyond.: 37.

58. Arnold CA, Researchers RJP. Resilience Justice and Community-Based Green and Blue Infrastructure. 45.

59. Willems JJ, Molenveld A, Voorberg W, Brinkman G. Diverging Ambitions and Instruments for Citizen Participation across Different Stages in Green Infrastructure Projects. UP. 2020 Mar 6; 5(1):22–32.

60. Lamond J, Everett G. Sustainable Blue-Green Infrastructure: A social practice approach to understanding community preferences and stewardship. Landscape and Urban Planning. 2019 Nov; 191:103639.

61. Ferreira V, Barreira A, Loures L, Antunes D, Panagopoulos T. Stakeholders' Engagement on Nature-Based Solutions: A Systematic Literature Review. Sustainability. 2020 Jan 15; 12(2):640.

62. Quality Assurance Standard for Community and Stakeholder Engagement [Internet]. IAP2 Australasia. 2015 [cited 2023 Feb 6]. https://www.iap2.org.au/news/quality-assurance-standard-for-community-and-stakeholder-engagement/

63. Adib M, Wu H. Fostering Community-Engaged Green Stormwater Infrastructure Through the Use of Participatory Geographic Information Systems (PGIS) [Internet]. DE: Wichmann Verlag; 2020 [cited 2021 Dec 9]. https://doi.org/10.14627/537690056

64. Dyer J. Assessing participatory practices in community-based natural resource management: Experiences in community engagement from southern Africa. Journal of Environmental Management. 2014; 9. https://doi.org/10.1016/j.jenvman.2013.11.057 PMID: 24632402

65. Hügel S, Davies AR. Public participation, engagement, and climate change adaptation: A review of the research literature. WIREs Climate Change. 2020; 11(4):e645. https://doi.org/10.1002/wcc.645 PMID: 35859618