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Drivers and barriers to knowledge exchange through an envisioned online platform for transdisciplinary research projects

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ABSTRACT

Transdisciplinary research requires improved knowledge exchange between science and practice. Such improvements include diversifying and scaling up knowledge accessing and sharing through online platforms. We conducted twenty interviews informed by behavioral science methods to clarify the aim, components, and participants' perspectives on the usefulness of the proposed components for an envisioned platform. Participants were members of a Dutch community of practice for river studies and a research programme into integrated and collaborative management. The proposed concept included storylines, data repositories, user profiles, interactive visualisations, and collaborative sessions. Interview results include drivers and barriers from prospective users that we translated into requirements to increase the potential adoption and effective use of online platforms with similar components. From the experiences with implementing these requirements, we provide recommendations for enabling primary drivers: (i) Combining online and offline interactions to provide various options for knowledge exchange between disciplines and organisations. (ii) Sharing the content and application of the research with a non-scientific audience. (iii) Reusing existing online platforms as much as possible without restricting any to improve the reuse of research methods and results. We further provide recommendations to overcome the main barriers: (i) Partnering with various communities to extend knowledge exchange. (ii) Following a participatory approach to improve the design and content while considering the time and resources that such a process entails. (iii) Providing flexible options to contribute and tailor overviews of available knowledge in different ways according to prospective users' roles in practice. (iv) Purposefully facilitating online interactions according to the transdisciplinary process-intended attributes.

1. Introduction

The increasing complexity of environmental management problems requires exchanging knowledge more effectively between research and practice to support better policy-making (Walsh et al., 2019; West et al., 2019). Transdisciplinary research projects are one of the means to address this call (Karcher et al., 2021). These projects facilitate high levels of collaboration across disciplines and prospective research users to address socially relevant problems, ideally starting from the societal actors' needs (Hakkarainen et al., 2022). Prospective users include practitioners such as advisors from consultancies, and the government, among other stakeholder organisations interested in or affected by the problem and solution strategies (Brouwer et al., 2018). Moreover, one can define knowledge as (Alavi and Leidner, 2001): a state of mind referring to an individual's mental models, beliefs, and viewpoints; an object that can be codified, stored, and manipulated; a process to create, share, and apply knowledge at individual and group level; and a capability inherent or developed by an individual or an organisation to inform actions. Therefore, knowledge includes the collected data, formalised or interpreted information that can be accessed and shared through reports, modelling outputs, or maps (Zulkafli et al., 2017). Knowledge also refers to the implicit and explicit data and information available through experience, discussions, or collaborative sessions (Kaiser et al., 2016). Knowledge exchange is further a process that

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includes various activities ranging from the co-production of knowledge to its actual use (Karcher et al., 2021).

With the growing capabilities of web services and the far-reaching connectivity of the internet, online platforms offer opportunities to support more relevant, intuitive, and unobstructed knowledge accessing and sharing (Zulkafli et al., 2017). Following He and Wei (2009), accessing refers to seeking available knowledge, while sharing refers to contributing knowledge to a given platform. Online platforms often include information management systems ranging from websites with content management systems to data portals for users to access, visualise, and upload available data and (geo-)information (Maurel et al., 2007). Decision support systems further allow users to interact with knowledge having partial or total control over data analysis and decision-making (Karpouzoglou et al., 2016). Collaborative platforms integrate the above components to diversify and upscale knowledge exchange by, for example, enabling users to divide tasks across geographic scales and participants (Wechsler, 2014) and facilitating knowledge sharing and peer learning through complementary tools (Jost et al., 2021).

Despite the promising capabilities to support knowledge exchange, the online platforms developed in transdisciplinary research projects do not necessarily lead to effective use and adoption beyond the project end (Lemos et al., 2019; Zasada et al., 2017). General recommendations to address this gap include (Karcher et al., 2021; Laudien et al., 2019; McIntosh et al., 2011): (i) A participatory and continuous user-centered design for the development of online platforms. (ii) Modular components and flexible design that acknowledge individual and organisational preferences. (iii) Better consideration of the role of communities of practice in facilitating knowledge exchange. (iv) Optimising available resources for long-term development and maintenance. Roadmaps for improving the effectiveness and use of online technologies suggest eliciting users' perspectives to select valuable components for these platforms as a preliminary step in the design process (Gemert-Pijnen et al., 2011). Previous studies on environmental knowledge management further used behavioural theories to investigate drivers and barriers to using online platforms (Wehn and Almomani, 2019) and derive user requirements (van Velsen et al., 2013).

This study aims to identify users' perspectives (i.e., intentions and preferences) regarding the usefulness of the proposed components for an envisioned online collaborative platform to support knowledge accessing and sharing in transdisciplinary research. In the context of a Dutch community of practice for river studies willing to improve its online knowledge exchange and a research programme into integrated and collaborative management, we investigated the following research questions through 20 semi-structured interviews with researchers and practitioners:

- What are the perceived drivers and barriers to accessing and sharing available knowledge through the envisioned platform?
- What are the design requirements for the potential usefulness of online platforms with similar components?

To this end, the paper structure is as follows: Section 2 outlines the aims of transdisciplinary projects to select the envisioned platform's key components and describe the theories we used to investigate user needs. Section 3 introduces the research setting and methods. Section 4 presents the results by grouping the derived drivers and barriers into requirements later described per component of the envisioned platform. Section 5 discusses our results based on the characteristics and challenges of transdisciplinary research. We further provide recommendations and reflections from our experience implementing some of the proposed components to researchers, coordinators of transdisciplinary projects, and developers of online platforms. Section 6 concludes with a reminder of the main findings, an outlook on this study's limitations, and the considerations for further research.

2. Conceptual framework

This section outlines the concepts and theories underlying our study to identify requirements that support the effective use of online platforms for transdisciplinary research in three subsections.

2.1. Key characteristics and challenges of transdisciplinary research

Transdisciplinary research projects aim at supporting more effective knowledge exchange by considering (Lang et al., 2012; Polk, 2015): (i) The inclusion of multiple disciplines, (non) academic groups, and societal organisations. (ii) Collaborative efforts that facilitate in-depth contributions of prospective users to increase the usability of the research outputs. (iii) Integration of various knowledge types from the problem framing to the application of the co-created knowledge. (iv) The assessment and reflection of the research process and results. As such, research activities should iteratively cover from defining the context, case studies, and making agreements for working together to integrating and applying the co-produced knowledge in scientific and societal practice (Horcea-Milcu et al., 2022). However, the extent and way in which transdisciplinary projects address the above aims have challenges including (Karcher et al., 2022; Lawrence et al., 2022): conflicting viewpoints over methodological standards, knowledge definition, and ways for integrating knowledge; significant time and resources needed from participants and coordinators, and the lack of comprehensive but context-specific assessment frameworks.

Nevertheless, the intended effects of transdisciplinary projects include (Karcher et al., 2021): (i) the usability of knowledge often described through attributes such as relevance, credibility, and openness, (ii) the actual knowledge use in policy, political, public and scientific debate towards wider impacts; (iii) social outcomes such as creating networks, minimising conflicts, facilitating learning, and trust building; (iv) process-related attributes such as inclusiveness, empowerment, and flexibility; (v) scientific or boundary products to facilitate knowledge exchange and (vi) personal outcomes such as ownership and satisfaction.

2.2. Key components for the envisioned platform

Online collaborative platforms can integrate various components, such as multi-user working environments, geospatial analysis, participatory data collection, and content management systems for knowledge accessing and sharing (Palomino et al., 2017). We focus on the functionalities of a content management system to inform this study's envisioned collaborative platform. However, we consider components that help the usability of knowledge within and beyond the project team (Múnera and van Kerkhoff, 2019).

The credibility and openness of the research require ensuring its findability, accessibility, interoperability, and reusability (Wilkinson et al., 2016). To this end, centralised repositories, documentation standards, category-based navigation, and keyword search components are essential to facilitate interoperability and to find relevant available knowledge (Kaiser et al., 2017). Due to the variety of prospective users, online platforms for transdisciplinary research should further facilitate knowledge sharing with different levels of detail and accessibility formats (Zulkafli et al., 2017). Online visualisation with charts and maps are helpful components that allow users to explore and interpret available knowledge (Vitolo et al., 2015), but it needs tailoring to the specific audience (Grainger, 2017). Since scientific reports may not sufficiently address practitioners, researchers are now looking for complementary ways to communicate the research's relevance, limitations, and application in practice (Cvitanovic et al., 2016). Such ways include framing available knowledge into storylines closer to practice (Bruijn et al., 2016) and using storytelling with multi-media elements and customisable displays to communicate the research relevance (Krzywinski and Cairo, 2013) and limitations (Spiegelhalter et al., 2011). User profiles

may be (or not) an intrinsic component of these platforms to support knowledge accessing and sharing tasks (Palomino et al., 2017). In either case, Hajli et al. (2015) further highlight the user profile's role in online communities for the credibility of less formalised knowledge, such as comments and experiences. Lastly, online groups may help to exchange knowledge beyond the project team by connecting users at remote locations with similar interests, facilitating working together, learning, and trust-building (Wechsler, 2014).

Although online platforms open up opportunities for transdisciplinary projects that otherwise might not be available, a critical stance is needed. On one side, individual knowledge and skills, organisational resources, and preferences for online knowledge accessing and sharing may become a barrier to inclusiveness (Dale et al., 2010). Conversely, online platforms may also amplify and scale up social processes that also occur offline, such as the polarisation of discussions. Without ethical regulation, these platforms may also ease the spread of misinformation that can ultimately lead to a breakdown of trust (Iandoli et al., 2021). Last but not least, online knowledge access and sharing should be carefully matched to the task and context of the research while considering that a combination of face-to-face and online interaction might be preferred, for example, to support the interpretation and learning about the knowledge accessed and shared (Lemos et al., 2019).

2.3. Behavioural theories to investigate user intentions and requirements

Previous studies suggest eliciting requirements per user type (Lai and Chen, 2014) and considering a wide range of influential factors to derive user requirements, including knowledge exchange, management, functional, content, user interaction, and design (Van Velsen et al., 2013). Moreover, knowledge management studies have typically built upon behavioural theories such as the Theory of Planned Behavior (TPB) and the Technology Acceptance Model (TAM) (Marangunić and Granić, 2015). Below we describe these theories as they relate to the influential factors of technology considered in the semi-structured interviews of this study:

- Developed by Ajzen (1991), the TPB assumes that the intentions for expected behaviour, such as knowledge accessing and sharing through an online platform, rely on users' beliefs or expectations regarding: (i) The advantages or disadvantages for individual, organisational, and expected societal outcomes. (ii) The circumstances that would make using the platform easy or difficult such as the user and organisational resources and technical characteristics. (iii) The perceived influence of individuals, groups, or organisations. Previous studies quantitatively survey or validate hypotheses regarding these influential factors to, for example, seek and contribute with available knowledge to online repositories (Kankanhalli et al., 2005a, 2005b) or reuse scientific data (Curty et al., 2017). However, our study better aligns with qualitative studies as it aims to derive user-centered requirements. Thereby, these theories are used as organising frameworks to describe influential factors into drivers and barriers derived from data collected through either literature reviews (Wehn and Almomani, 2019), surveys, or interviews (Gharesifard and Wehn, 2016).
- Based on the TPB, Davis (1989) proposed TAM to investigate the acceptance of technology by considering the degree to which a person believes that using the technology is free of effort (ease of use) and is expected to enhance the user's performance (perceived usefulness). We are particularly interested in this theory to complement the TPB insights by asking users to self-report their experience with the technology (Fusilier and Durlabhji, 2005). Moreover, we aim to

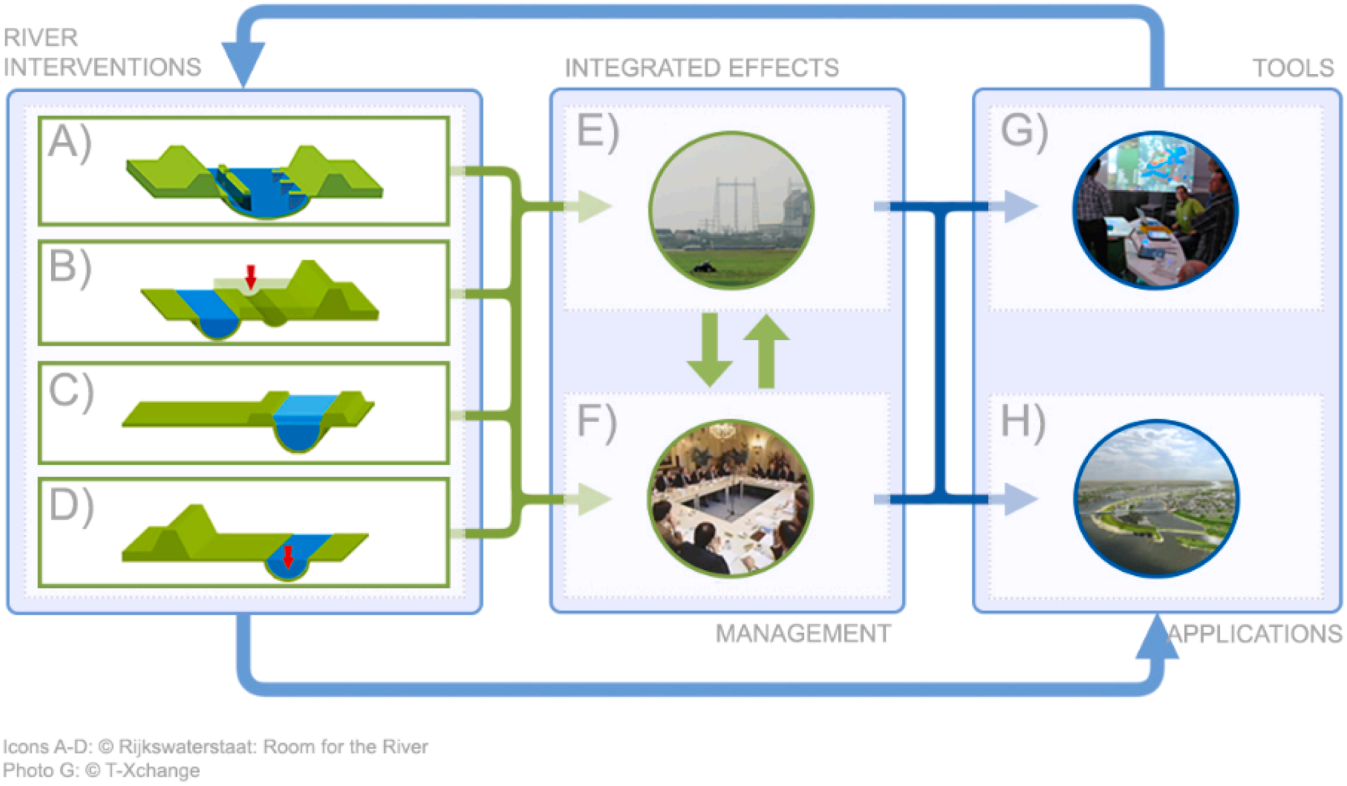

Fig. 1. RiverCare's eight project themes include A) Optimising the longitudinal training dams design; B) Side channels and natural banks; C) Regional water systems; D) Sediment nourishment; E) Ecosystem services and floodplain rehabilitation; F) River Governance; G) Communicating program output, and H) Self-supporting hydro-systems and valorisation.
Source: adapted from Hulscher et al. (2016).

Table 1
Components of the envisioned platform.

Components	Proposed description
1) Storylines	Interactive and easy-to-follow storylines are used to share the research objectives, assumptions, or results with a broader audience. Users can access links related to research results and join available discussions along with the storyline.
2a) Data Repository	A data repository allows researchers to have a user profile for managing their data and storing their input, process, and output results. Users can access datasets that have been published upon request.
2b) User profiles	Upon registration, users will be asked to enter a user profile according to their background or discipline. Users can share contact details, interests, and relevant links to their experiences in their profiles. Users can also follow the updates of other users with similar interests.
3) Using available results	Interactive maps and charts will facilitate users to visualise and compare (geo)-spatial information related to research outputs. Users can access an indication about contributors, limitations, and usage of research datasets.
4) Querying of content	Available content in the platform is categorised by topic, such as location, river function, user group, resources, and collaborative sessions, such as online discussions. Users can also query available content according to their management interests, i.e., the effect of river management measures.
5) Collaborative sessions	Every session is initiated by a facilitator who invites others to contribute. You can join in agreeing on the objective, ways, and period of collaboration. An overview of each session will be presented to registered and non-registered users. Open sessions are about the discussions of the topic at hand. Private sessions are groups created to work together on a specific issue.

derive requirements for specific components by discussing with users the proposed features (Minkman et al., 2016).

3. Research setting and methods

We carried out this study under the Netherlands Centre of River Studies (NCR) umbrella and as part of the RiverCare research programme. The NCR is a community of practice with about 500 members from Dutch institutes for river studies (Berends, 2021). Members typically coordinate efforts to integrate available knowledge, facilitate discussion and promote excellent science through, for example, the implementation and dissemination of research projects of diverse sizes and scopes. RiverCare (2014–2019) proposed new methods, tools, and applications for integrated collaborative management and transdisciplinary research. Twenty researchers worked with representatives of governmental and private organisations on eight project themes (A to G, Fig. 1). Themes ranged from fundamental to applied research looking at the river interventions' design to create more space for the river while considering the ecological and river dynamics effects.

As part of RiverCare's communication theme, we proposed to develop an online collaborative platform to support knowledge exchange between research and practice. Informed by the conceptual framework (Section 2.1), we prepared a video explaining our vision of such a platform (**Appendix A**). Table 1 summarises the proposed platform's components. The following subsections elaborate on our methods to clarify the aim, components, participants' intentions, and preferences regarding the envisioned platform.

Supplementary material related to this article can be found online at doi:10.1016/j.envsci.2023.06.009.

3.1. Semi-structured interviews

We held 20 interviews between May and June 2016 with representatives of the RiverCare program partner organisations. To voluntarily participate in the study, we invited representatives of organisations in the RiverCare users' committees. These committees were established from the onset of the programme to define the scope and facilitate the research, following the requirements of the funding agency. We focused on the representatives involved in two project themes: One assessed the effects of the river and floodplain management in the vegetation and aquatic habitats (**E in** Fig. 1). The other one looked at the model uncertainty, participatory monitoring, and collaboration (**F in** Fig. 1). We chose these themes because their representatives included various disciplines and types of stakeholder organisations. Thereby, half of the interviews (thirteen) were with participants directly related to RiverCare, whereas the others (seven) were interested but not involved. The respondents were mainly affiliated with Dutch organisations as follows: research or academic institutions (seven), consultancies (six), government (four, including two affiliated with an international, non-Dutch organisation), and other stakeholder organisations (four). One interview was with two participants of the same stakeholder organisation. The scope of the interviews was broader than this study and was divided into three parts to identify respondents': (i) experience in working with multiple actors in river management; (ii) intention to use the proposed component; and (iii) intention for accessing and sharing knowledge via the proposed online platform. This study reports the analysis of the second and third interview parts in which we explicitly discussed the online platform. The analysed interview questions are available in **Appendix B** of the supplementary material. Table 2 describes these questions according to the answer options and the theories we introduced in the conceptual framework (**see** Section 2.1).

The first author carried out all interviews in English and recorded them upon the respondents' agreement. Each interview lasted for about two hours. Seven interviews were on Skype due to the remote location of the participants. At the start of the interview, participants first watched the video sent before the interview to discuss their understanding of and interest in the proposed platform. Afterward, we discussed each component separately in the order that participants preferred. We used Appendix B as interview guidance to note down participants' responses. We asked participants to rate each component using a 7-point Likert

Table 2
Description of the analysed interview questions.

Interview part	Reference theory	Interview question	Answer options per question	Applicable component
Intention to use the proposed component	Technology Acceptance Model (TAM)	Clarity and interest in the envisioned platform Agreement with the component description Potential usefulness for work or interest Previous experience with the component	Rating and open-ended questions to add or give examples	Envisioned platform as a whole Each component of the platform
Intention for accessing and sharing knowledge via the proposed online platform	Theory of Planned Behaviour (TPB)	Examples of the knowledge to be accessed or shared through the platform Potential advantages or disadvantages Circumstances that would make it easier or difficult Influence of individuals, groups, or organisations	Open-ended questions	Envisioned platform as a whole

scale from 1 (strongly disagree), 4 (neither/either), to 7 (strongly agree). We followed each rating with an open question for participants to explain their answers. Subsequently, we asked open questions to elicit participants' expectations regarding using the envisioned platform.

3.2. Interview data analysis

We first analysed interview questions about clarity and interest to identify the users' intentions and preferences regarding the envisioned collaborative platform. After that, we looked at the level of agreement, potential usefulness, and previous experience with the proposed components. To that end, we first categorised the ratings on each component into a low agreement (1 and 2 ratings), undecided (3, 4, and 5), and high agreement (6 and 7). By distinguishing between researchers and practitioners, we calculated the number of participants per rating category, the mean, and the standard deviation. Since ratings only illustrate general preferences, we conducted an inductive analysis of the verbatim transcripts. According to van Velsen et al. (2013), we selected quotes worth translating into requirements when participants elicit their wishes or interest in the online platform components while summarising their needs according to the interview question. Thereby, we identified participants' drivers and barriers for potentially using the platform while gathering examples about the type of knowledge they expect to access or share via the following steps:

- The first author coded all the transcripts assigning the following requirement categories: knowledge exchange, management, functional, content, user interaction, and design.
- The second author coded five interviews. Then, the first author refined the coding scheme to apply it to the rest of the interviews. The third author reviewed the coded transcripts.
- When brought forth by participants multiple times, we assigned codes only once per component or interview question. We counted the absolute frequency of each code according to the participants' affiliation as a researcher or practitioner. The latter included consultants and representatives from government and stakeholder organisations.
- The identified drivers or barriers emerged according to the question in which the quote was brought forth (disadvantage, advantage, circumstances that will make it easier or difficult, constraining or encouraging organisations, and other suggestions). The frequency does not directly indicate the importance and only shows the number of participant mentions.

4. Results

Below, we first report the identified drivers and barriers to accessing and sharing available knowledge via the envisioned platform by grouping them into requirements. Subsequently, we report these requirements per component.

4.1. Drivers and barriers to using the envisioned platform for knowledge accessing and sharing

The expectations of researchers and practitioners to use the envisioned platform was more about accessing than sharing knowledge. Although some participants were willing to access scientific papers, reports, and datasets, participants also mentioned accessing visual results into (info)graphs, maps, and photos to get a summary of projects' objectives, activities, findings, and recommendations. For example, visual searches and navigation were also referred to find the location(s) of past and ongoing (research) projects. Participants would share related links to, for example, available datasets, publications, experiences from the research and the collaboration, and answers to specific questions. However, their intention to put effort into sharing through the envisioned platform relied on their direct relationship with the project team, the platform's actual availability, and the data owners' permissions. When looking into the drivers and barriers that may positively (+) or negatively (-) influence participants in using the envisioned platform, Table 3 summarises these results from the aggregated perspectives of researchers and practitioners. We grouped these drivers and barriers into five requirement categories detailed in the following subsections based on the results of **Appendix C**.

4.1.1. Knowledge exchange-related requirements

The most recurrent driver was the possibility of downloading, building on, or reusing available knowledge (N = 11). However, other drivers include when knowledge from multiple sources is shared (N = 6) and when the knowledge exchange allows improving connections (N = 8), enhancing partnerships or acquiring new projects (N = 3), and sharing with others what the research is about (N = 6). Regarding knowledge exchange, participants reported that the various disciplines and organisations contributing might encourage them to use the envisioned platform, particularly when prospective users include government representatives and other stakeholders. A representative of a government organisation further mentioned that the actual use of the envisioned platform requires encouragement from a professional community (17-US-AU).

4.1.2. Management-related requirements

Participants perceived management-related factors as the most significant barriers. Confidentiality and intellectual property restrictions of available knowledge were a concern (N = 10), given that data management plans and open access to research data were just set mandatory by the funding organisation at the interview time. A suggestion to address these restrictions was to set up accessibility rights into the platform within specific groups or members (1-RE-KI). Conversely, a recurrent barrier was the time and financial resources to develop and maintain the envisioned platform (N = 10) and populate it with up-to-date content (N = 9). Therefore, participants generally called for easing the efforts and motivating prospective users to contribute to the platform. To optimise management efforts, a representative from a research institute also referred to the possibility of "*us[ing] this platform as a template to easily set up a new project-specific platform for another project*" (1-RE-KI). Partner organisations may be encouraged to use the platform if they could also use it for their projects (N = 4). Last, participants mentioned dissemination efforts through relevant organisations, partners, and networks as a driver to create awareness about the platform and encourage prospective users to access and sharing (N = 4).

4.1.3. Functional-related requirements

Getting an overview list of available knowledge and actors involved was one of the main advantages of using the envisioned platform (N = 9). Searching and accessing knowledge simply and quickly was another important advantage that would either encourage, ease or make difficult use of the platform (N = 11). Other (dis)advantages were building on or reusing existing tools and open-source technologies (N = 6). Example disadvantages are when the relation or difference with institutional platforms is unclear (15-US-AU) or when efforts get fragmented by bringing another tool for the same thing (6 and 14-RE-KI). To ease the interaction with the platform and encourage prospective users, participants also commented on using common and easy-to-use software (N = 4) and facilitating the usage on multiple devices (N = 2). Last, the possibility to choose the language was also an advantage for accessibility but also a constraint when not considered (N = 5).

4.1.4. Content-related requirements

Besides having up-to-date knowledge (N = 4), participants first considered the knowledge quantity, quality, and findability as an advantage that would make it easier or encourage them to use the platform (N = 17). However, participants also considered quantity a disadvantage or difficulty when the scope of the content is too limited,

Table 3
Number of times that participants listed according to the interview question and the requirement category: drivers, when positively (+) referring to the usage intention (shaded in green); barrier when negatively (-) referring (shaded in red), or suggestion with indistinctive (o) reference (shaded in gray).

Drivers (+) or barriers (-) per requirement category	Potential advantages/ disadvantages		Circumstances that make it easier or more difficult		Influence of related individuals or organisations		Other	Total number of mentions
	(+)	(-)	(+)	(-)	(+)	(-)	(o)	(N)*
Knowledge exchange	17	1	2		11		3	33
The connection between multiple disciplines and organisations	3				5			8
Possibility to download, build on or reuse available knowledge	6	1	2		1		1	11
Possibility to enhance partnerships or acquire projects	2				1			3
Possibility to share with others what research is about	4				1		1	6
Shared knowledge from multiple sources	2				3		1	6
Management	1	13	6	4	7	4	2	37
Access restrictions, confidentiality issues, or intellectual property constraints		4		1		4	1	10
Dissemination efforts through relevant organisations, partners, or networks					4			4
The effort to store, join or provide knowledge to the platform or its components		5	3		1			9
Efforts for development, management or maintenance of the platform or its components		4	2	3			1	10
Generalisable design of the platform or its components applicable to other projects	1		1		2			4
Functional	12	2	16	2	2	1	2	37
Build on or reuse existing platforms, tools, and open source technologies	1	2	3					6
Fast/easy access and search of available knowledge	4		5	1	1			11
Overview list of available knowledge and actors involved	6		3					9
Possibility to choose the language of the content	1		1			1	2	5

(*continued on next page*)

Table 3 (*continued*)

Drivers (+) or barriers (-) per requirement category	Potential advantages/ disadvantages (+)	(-)	Circumstances that make it easier or more difficult (+)	(-)	Influence of related individuals or organisations (+)	(-)	Other (o)	Total number of mentions (N)*
Use of common and easy-to-use software			2	1	1			4
Use of the platform or its components on multiple devices			2					2
Content	15	7	13	2	4	3	2	46
External links for explanation or additional information			1					1
Knowledge quantity, quality and findability	8	5	1	1	1		1	17
Procedural information on how the knowledge is produced	2		2					4
Selection of information (not all knowledge is relevant for all users)			2			1		3
Understandable presentation of available knowledge	1	2	3	1	2	2		11
Updated knowledge on the platform and its components	2		1		1			4
Use of appropriate visualisations (maps, graphs) for the knowledge available	2		3				1	6
User interaction and design	4	4	11	6	1	2		28
Easy navigation and good interface design of the platform or its components		1	8	4				13
General user experience and effort to use the platform		1	2	2				5
Options to contact actors involved	3							3
User profile options		2			1	1		4
Options to react or give feedback	1		1			1		4

*The total number of mentions (N) does not relate to the total number of interviews given that a participant could refer the same driver or barrier into any of the interview questions (disadvantage, advantage, circumstances that will make it easier or difficult, constraining or encouraging organisations, and other suggestions).

or the amount seems overwhelming to find the knowledge of interest. Next, an understandable presentation of the information using appropriate visualisations with, for example, maps and (info)graphs (N = 6) was mentioned as a driver that, when lacking, may become a barrier for non-experts (N = 11). In addition, proper documentation was also perceived as an advantage that would make easier the interpretation of collected data (N = 4). Despite the importance of selecting and tailoring content for prospective users, it may become a constraint for sharing due to the required effort for knowledge contributors and managers of the envisioned platform (N = 3).

4.1.5. *User interaction and design-related requirements*

Easy navigation and well-structured user interface design were the most mentioned facilitating circumstances that, when lacking, may become a disadvantage or make the interaction difficult (N = 13). Some of the difficulties are the number of clicks and layers to access the information and the loading time for interactive elements such as maps, which may ultimately affect the general user experience and the perceived effort of use (N = 5). Overall, user profiles were considered a disadvantage due to the need to be updated (N = 4). Moreover, preferences for interaction between users were split. Some participants preferred to contact the actors involved directly (N = 3). Others preferred to react or give feedback through the platform by, for example, posting replies to comments and general questions (N = 4).

4.2. *Requirements for the potential usefulness of the envisioned platform and its components*

When asked to reflect upon the concept video of the envisioned platform, participants would have preferred a more concrete example. General concerns were about choosing a target group, either researchers or practitioners. Moreover, participants further requested specifying the uniqueness of the envisioned platform and its components regarding other existing platforms. More specific suggestions included preparing a business plan to guide the development and maintenance (12-US-PR) and a communication strategy to populate and disseminate the platform (1-RE-KI). Referring to each component, Fig. 2 shows the relative frequencies of participants' responses grouped into low, undecided, and high ratings for researchers (7 interviews) and practitioners (13 interviews). Participants' ratings mainly were from undecided to positive.

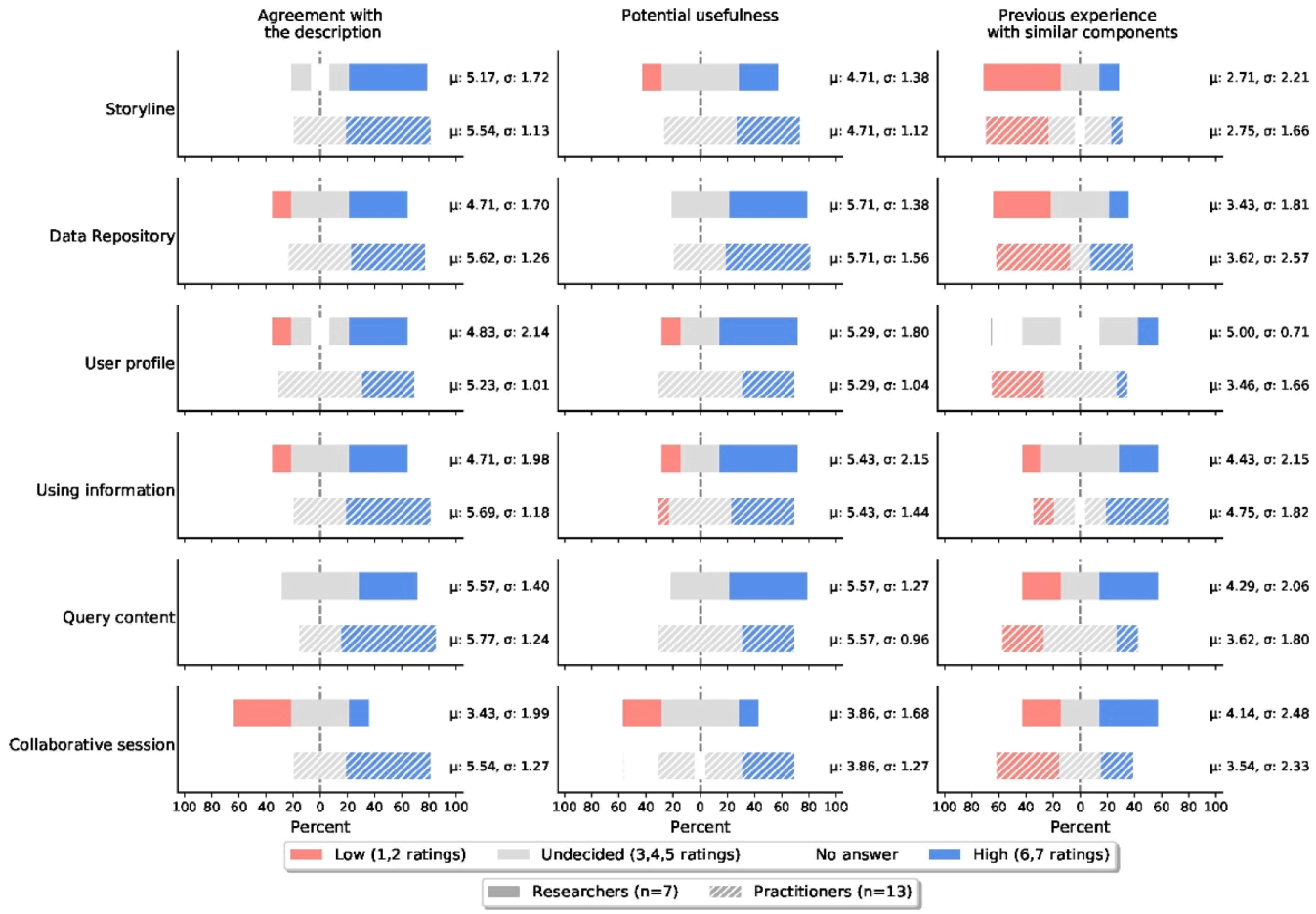

Fig. 2. Relative frequency of participants' responses per component and interview question using a Likert scale from 1 to 7, whose results we grouped into low, undecided, and high ratings. Results correspond to 20 interviews, one of which was carried out with 2 participants.

Despite the limited number of interviews, researchers were more critical of components such as the storylines, data repository, user profile, and collaborative sessions. For the component of using available information, both groups have similar ratings. Overall, previous experience examples were limited. The following subsections report the most recurrent requirements per component elicited by researchers and practitioners while distinguishing when a requirement was mentioned only by a participant group (**Table A2**).

4.2.1. Storylines

Participants' mentioned examples were very diverse and referred to videos, project websites with discussion fora, visually attractive elements, and databases with interactive visualisation. Therefore, most recurrent comments were to clarify the content and use of the storylines. Participants may use the storylines to put research results into a simple and straightforward context (N = 10) by, for example, referring to a location or a case study (N = 3). However, experts may need another way of accessing knowledge in their field (N = 8). Therefore, narrowing down the target group is important for the storylines (N = 5). Next, knowledge exchange requirements included suggestions for showing the added value of the research (N = 7) and summarising the project, its timeline, and the actors involved (N = 6). Practitioners referred to using the storylines to learn about projects they are unfamiliar with (N = 3). Elements that prospective users could engage with were also important (N = 3). A specific suggestion referred to the application of research in (future) river interventions (12-US-PR). Finally, functional-related requirements mainly focused on providing easy access to the knowledge of interest (N = 7) via search and navigation options when necessary (N = 6). Regarding user interaction and design, participants requested visually attractive, easy-to-follow, and responsive elements (N = 3). A consultant (4-US-PR) and a representative of a stakeholder organisation (2-US-SH) would remain like content suggestions according to their user profile.

4.2.2. Data repository

Participants mainly referred to the examples of government, case studies, or university websites, including overviews of datasets or research projects. Therefore, functional-related requirements were about reusing existing data repositories whenever possible (N = 4). Participants were expected to get knowledge available at a given location or time (N = 4). Regarding user interaction requirements, preferences were mainly about having options to contact and ask questions to the data contributors (N = 5). Moreover, practitioners must minimise the effort to navigate (17-US-AU) with a more intuitive user interface (13-US-PR). Participants mostly acknowledged the benefits of downloading and reusing datasets, methods, and results (N = 10) for the knowledge exchange requirements, particularly when using a central repository (N = 8). In addition, practitioners would like to know about the data limitations (5-US-AU) and follow the intended use upon data requests (N = 2). For the content, participants requested to have enough knowledge of sufficient quality (N = 4) that is available beyond the project scope (N = 3) and end (N = 5). Data documentation was also mentioned by following metadata standards (N = 5). However, from the management perspective, participants were concerned about the time and effort to upload content (N = 6). To that end, researchers may simplify documentation by linking it to the underlying report (14-RE-

KI). Despite the interest in promoting open access (N = 4), participants also recognised access restrictions (N = 6), which may ultimately limit or delay knowledge sharing (N = 2). Therefore, researchers suggested including data sharing as a funding requirement (N = 3).

4.2.3. User profiles

Participants referred to examples of platforms such as LinkedIn, ResearchGate, or their organisations' websites where they already have and regularly update their user profiles. Therefore, most participants considered it important to reuse existing profiles (N = 12), limit the profile's content, or not have a user profile for the envisioned platform (N = 2). In either case, participants would like easy access to contact details (N = 4) and possibilities for asking questions to data contributors (N = 3). Some practitioners mentioned the advantages of accessing and searching content in the platform by, for example, defining their preferences on the user profile (N = 2). However, profile options should follow data protection regulations (N = 2) and minimise the number of reminders and follow-up emails (N = 5). Knowledge exchange requirements were mostly about grouping a professional community (N = 6) to help learn, discuss, and share experiences (N = 6). Given the possibly limited number of users for knowledge exchange (N = 3), participants also suggested joining an existing community (N = 3) to limit the management efforts (N = 2).

4.2.4. Using available results

The proposed description for using available results was divided into two parts: usage indication of research datasets and interactive visualisation. For the usage indication, requirements included specifying limitations and usefulness of available knowledge (N = 5). To that end, some participants may have enough with a link to the underlying report (N = 5), while others may prefer reference to the added value of the research (N = 3). This reference is, for example, by putting results into a simple and straightforward context (N = 5) to support the decision-making of (future) interventions (N = 3). Interactive maps and charts were considered useful (N = 6). In addition, participants referred examples to widely used software such as ArcGIS or Google Earth. They also referred to the government and their organisation websites when available with online mapping applications. Functional requirements were mainly concerned with an overview of knowledge available at a given location or time (N = 6). Yet, a practitioner also suggested referring to the actors involved (4-US-PR). Content-wise, participants expected visuals that help to understand (N = 5). Particularly, practitioners suggested reference to a location or case study (N = 5) and changes over time (N = 3). In either case, participants suggested limiting the complexity of the maps and charts' content (N = 4) and the navigation options (N = 3). Overall, participants further suggested reusing or building this component on existing solutions (N = 4) to minimise development (N = 2) and maintenance efforts (N = 2).

4.2.5. Querying of content

For this component, participants typically referred to searches on a map, keywords, and tags from photography software and websites with a large amount of information, such as newspapers. Functionally, this component may be useful to inspect the overview lists of available knowledge at a given location or time (N = 6) via navigation and search options (N = 4). Indeed, most participants agreed with defining tags that help find and filter content (N = 13) by, for example relating the keywords with the decisions to take or the effects of (river) interventions (N = 4). Moreover, some researchers required some flexibility to define these keywords (N = 4), while others suggested making the platform and its content indexable by search engines (18-RE-KI). The goal is to minimise the time and effort to search (N = 9) and navigate (N = 3). Moreover, participants suggested having different ways of finding related content (N = 3) and appreciated a preview of the content by including visually attractive, easy-to-follow, and responsive elements (N = 2).

4.2.6. Collaborative sessions

Practitioners were mainly interested in collaborative sessions for learning, discussion, and sharing experiences (N = 4). Instead, researchers may use these sessions to enhance partnerships (N = 2) while discussing, for example, the potential research applications for decision-making (N = 2). However, all participants suggested having some flexibility to participate. For practitioners, for example, this is by having regular and multiple types of sessions and topics (N = 7). For researchers, it was also important to follow without actively contributing (N = 2). Although some practitioners consider it useful to post comments through the platform (N = 2), the general preference seems to be a session with a specific goal and output (N = 5), including external links for related information (8-US-PR). To minimise efforts for both organisers and attendants, the collaborative sessions may require some registration (N = 2) and have limited duration and preparations (N = 5). Researchers would like to follow without necessarily contributing (N = 3). Overall, participants preferred a moderator to facilitate the discussion (N = 7). When asked to refer to examples, participants referred to various communication platforms to work together or network and included other online communication methods such as webinars and online courses (N = 7). Therefore, participants suggested reusing an existing platform to host these collaborative sessions as much as possible (N = 6). Thereby, the development (N = 2) and maintenance (17-US-AU) efforts can be minimised, given that a good user experience is important (N = 4). Several participants may still prefer face-to-face meetings and collaborative sessions (N = 7).

5. Discussion

We discuss the most frequent drivers and barriers to adopting and using online platforms, referring to transdisciplinary research's key characteristics and challenges. We further provide recommendations from our experiences implementing some of the proposed components and reflect on their adoption and effective use.

5.1. Considerations for enhancing the use of online platforms

Our results show that expectations about knowledge accessing and sharing at the science practice interface are also about improving knowledge accessibility, reusability, and applicability and not only about relevance, openness, and credibility (Dunn and Laing, 2017). To this end, Table 3 defines accessibility across multiple dimensions, including functional (i.e., fast/ easy access, and an overview of available knowledge), content (i.e., quantity, quality, and understandable presentation, for example, through appropriated visualisations), design (i.e., easy navigation and interface) and management (i.e., confidentiality and intellectual properties). Moreover, knowledge is not limited to what one can access and is available for download (Alavi and Leidner, 2001). Reusability and applicability are drawn upon research process-related attributes and social outcomes (West et al., 2019). For example, trustworthy relations between research and practice are necessary to develop the connections and partnerships that can ultimately lead to the individual and organisational capabilities for reusing and applying knowledge in practice (Karcher et al., 2021). In either case, the actual use in policy, political and public debate toward wider impacts further requires researchers to be aware of the windows of opportunity and the dynamics beyond the scientific debate (Cairney and Kwiatkowski, 2017). Moreover, improving knowledge accessibility has implications for sharing the co-produced research and requires the support of researchers and practitioners. Despite the variety of prospective users, suggestions were to tailor research knowledge to experienced but less specialised practitioners while considering their role in practice (Charband and Jafari Navimipour, 2016; He and Wei, 2009).

However, participants had different preferences for enhancing these drivers through the proposed components. Overall, they questioned the need to host collaborative sessions through an integrated online

platform that may not be friendly enough for prospective users compared to the standalone applications that participants may use (Lin, 2006). For example, wide social networks offer possibilities for posting opinions and creating discussion groups among participants with different backgrounds (Krätzig and Warren-Kretzschmar, 2014). These are typically large online communities where prospective users may already have an up-to-date user profile. Moreover, participants noted the need to motivate users and the combination of online and offline sessions, to actively access and share knowledge (Lai and Chen, 2014). For reusing available datasets, models, and reports, participants preferred online data repositories (which may be available at the organisational level), supporting large storage, multiple formats, documentation capabilities, and long-term access (Dwyer et al., 2015). Since prospective users have little time for searching and interpreting available scientific publications and datasets (Fabian et al., 2019), participants were enthusiastic about components such as storylines and interactive visualisations. However, they also warn that using such interactive online components may be influenced by their experience with the research topic and how easy and intuitive the online interaction is (Xexakis and Trutnevyte, 2019). Some users may still prefer short but less interactive formats such as policy briefs combined, for example, with interpersonal communication (Jacobi et al., 2020). Participants further suggested exploring different forms of visualisation but clarifying the online platform's aim to either attract non-scientific audiences or support users who wish a deeper understanding of available knowledge (Newell et al., 2016).

In alignment with the above main drivers, recurrent barriers results were related to ensuring that knowledge is discoverable, accessible, and understandable to prospective users (Cvitanovic et al., 2016). However, online research platforms are typically jargon-driven, limiting the interpretation and use of available knowledge, and do not sufficiently consider design and interaction needs (Hewitson et al., 2017). Participants recognised the knowledge quantity and user numbers as drivers that may scale up accessing and sharing while increasing the competitive value of online platforms (Alajmi, 2012) and pointed out some barriers. On one side, the volume and level of detail of available knowledge may require more effort from prospective users to find and interact with relevant information (Arciniegas et al., 2013). On the other side, despite the number of prospective users of an online community, active, loyal, and committed users are key to ensuring the success of (online) collaborative platforms (Tang and Liu, 2015). Therefore, the management of these platforms should consider mechanisms to attract new users and maintain and activate the online community over time (Jerome, 2013). In this regard, participants recognised the efforts for development and maintenance as the major barrier to use. To minimise these efforts, participants suggested reusing scalable, customisable, and open-source solutions as much as possible (Palomino et al., 2017). Furthermore, participants acknowledged the role of partner organisations in promoting knowledge accessing and sharing through online platforms (Pfaff and Hasan, 2011).

5.2. *Recommendations from the experiences with implementing some of the proposed components*

Regarding the envisioned platform, Fig. 3 summarises the simpler NCR online platform developed with a multi-site structure (NCR, 2020).

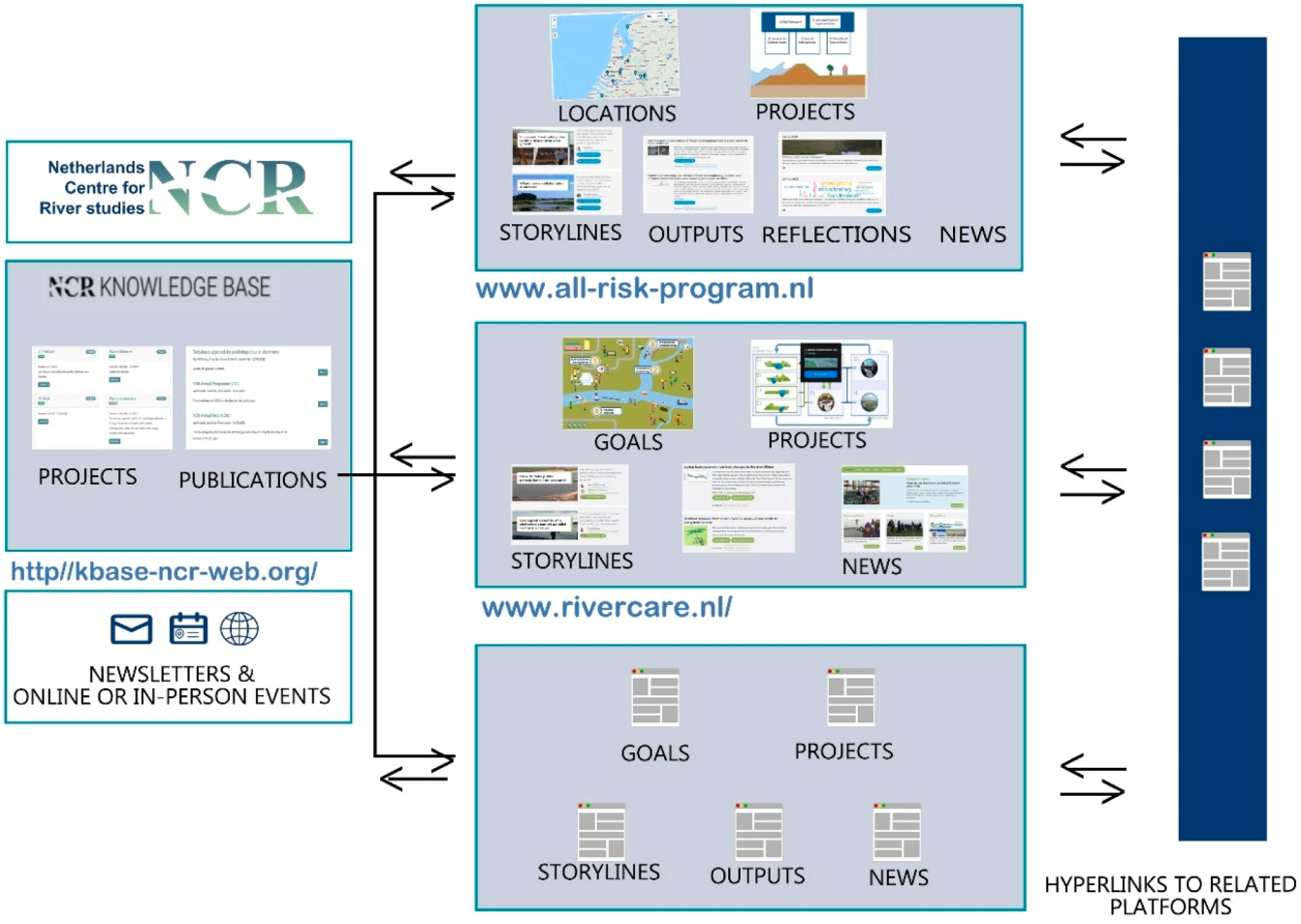

Fig. 3. The final concept of the (online) collaborative platform for transdisciplinary research projects was first developed for the RiverCare programme with the support of the Dutch community of practice for river studies (NCR), followed by three similar programmes of the network.

Such structure provides the overview of the projects and outputs of the community of practice across sub-sites on the main site. Current and future large NCR research projects can adapt the subsite template to their visual identity and provide a dedicated overview of their project structure and research outputs to interested professionals. Smaller projects that prefer not to have a separate subsite are featured on a single page under the main site. Moreover, we diversified knowledge sharing by combining regular e-newsletters, dedicated thematic sessions (online, in-person when possible, indoors or outdoors), and conferences to support formal and informal learning and discussion. From our experiences with implementing this concept within and beyond the RiverCare end, we draw the following recommendations, also supported by previous studies:

- Follow a participatory approach to improve the design and content but consider the time and resources that such a process entails (Valls-Donderis et al., 2014). This study was the first step of a participatory and iterative design process for a generalisable design. We followed the results by deriving user descriptions that inspired the website design (van de Bildt et al., 2018). The preliminary design was later refined via interviews with representatives from the RiverCare themes that were not part of this study. Via a clickable prototype, we improved the attractiveness, navigation, and visual overview of the subsite template (Nooren, 2018). Overall, the final website was launched towards the end of the programme (RiverCare, 2019), which limited its actual use beyond the programme team. However, the subsite template has been adopted and taken forward by the NCR community of practice.
- Make an implementation plan, a business model, and a comprehensive assessment plan to account for the online platform's adoption, use, and maintenance (Limburg et al., 2011). Developments of online technologies in transdisciplinary research often make these plans later in the development process (Zasada et al., 2017). Based on the results of this study, we started earlier with the organisations involved and the private company to which the multi-site development was outsourced. However, the quality of online and offline interactions still relies on the available resources for communication of each research project, which ultimately influences the extent of the knowledge exchange and website usage.
- Develop a communication strategy that considers partnering with various communities of practice (Mea et al., 2016). In RiverCare, we did embed the platform development into the online and in-person activities of the NCR community of practice. However, we also contributed to relevant existing networks and platforms identified through this study to ensure a more comprehensive reach of the available knowledge and attract website visitors. Although these contributions helped tailor the content to the audience of each platform, the combination of regular online and offline events with other communities of practice was more efficient for triggering visitors to the RiverCare site.
- Provide flexible options to contribute and tailor overviews of available knowledge in different ways according to prospective knowledge users' role in practice (Laudien et al., 2019). Through these five years of experience, we assisted researchers in sharing their projects on the website and facilitated online discussions with practitioners during the COVID period. We prepared example applications via storylines, which we interpreted as a visual and interactive summary (Cortes Arevalo et al., 2020) rather than exploratory scenarios (Shepherd et al., 2018). Some project overviews, example applications, and discussion outputs are also published in an e-book (Kok et al., 2022). Planning such activities required an editorial and creative team, which was best arranged as a team project effort with external support according to the communication needs. External support is important to overcome knowledge-sharing barriers, such as competing priorities or limited expertise to tailor available knowledge (Charband and Jafari Navimipour, 2016). Yet, knowledge access and discovery are somehow limited to the NCR community. Therefore, partnering with other related communities is instrumental in reaching a wider audience.
- Purposefully facilitate online interactions according to the process-intended attributes within and beyond the project team, such as inclusiveness, empowerment, and flexibility (Karcher et al., 2021). Transdisciplinary projects should not only focus on co-producing usable knowledge about the problem, the solution strategies, or ways of implementation. Such projects should also nurture individual and organisational capabilities that facilitate knowledge reusability and applicability, such as critical thinking and agency (Kueffer et al., 2019). This study was carried out before the COVID-19 pandemic, which restricted in-person meetings and pushed most people to collaborate online. Since then, some transdisciplinary projects have shared the pros and cons of using online platforms to support research activities (Sattler et al., 2022). Online platforms reduce the time and resources needed from participants and scale up knowledge accessing and sharing. However, online interaction cannot replace the (regular) face-to-face interaction that might still be necessary to facilitate social outcomes such as mutual learning, conflict resolution, and trust building, which can, in turn, increase personal outcomes such as ownership and satisfaction.

5.3. *Reflections on adoption and effective use*

Our results highlight attributes of online platforms that may lead to adoption and effective use. Although this is an essential ambition to strive for, one should also acknowledge that it goes beyond considering users' perspectives (Song et al., 2018). Web services grow quickly, and online technologies that looked upfront a few years ago now feel outdated. Therefore, considerations for a long-lasting lifetime for developing and using online platforms should also account for the need to update and redesign.

Regarding adoption, we saw that three similar programmes of the NCR embraced the website template (All-Risk, Rivers2morrow, and Salti-solutions) and have so far benefited from the process and lessons learned from this study. The storylines component further informed developments of a different platform focusing on visual storytelling or "scrolly-map" but using open-source technologies to, for example, communicate the effect of the drought on the shipping traffic in the Netherlands (Deltares et al., 2023). We can expect that some of these adoptions will continue from an evolving technological landscape while others revive in another form.

Regarding effective use, this study focused on the expectations of prospective users (ex-ante) and not on the actual user experiences with the implemented components (ex-post). Future research should address this limitation to develop further a framework for regular assessment and reflection on how online platforms contribute to the intended effects of transdisciplinary research. This assessment should not limit to website usage but consider knowledge usability as a whole (Jacobi et al., 2020).

6. Conclusions

Via this interview study, we identified perceived drivers and barriers and derived design requirements to improve knowledge exchange through an envisioned online collaborative platform. Barriers are generally related to the platforms' management, content, and design. The main drivers are about enhancing: (i) Various and flexible online and offline options for knowledge exchange between representatives from multiple disciplines and organisations. (ii) The accessing and sharing of the summary and application of the research to non-scientific audiences. (iii) Reusing existing online platforms as much as possible without restricting any to improve the reuse of methods and results. Although participants in this study were limited to representatives of the RiverCare partner organisations, findings apply to broader communities of practice interested in using online platforms with similar components.

From experience with implementing these requirements, we draw some recommendations for enhancing identified drivers and overcoming main barriers:

- Overall, participants suggested not limiting the interactions between research and practice to a single platform or an online environment to diversify best and scale up knowledge accessing and sharing. In-person interactions can better complement and trigger further online interaction while facilitating collaboration via trustworthy knowledge and relations.

- Participatory design and partnership with professional communities can help the management and improve content tailoring and future adoption of online platforms, but it is a resource-demanding process. The actual use for knowledge exchange still relies on the availability of the actual online platform and the collaboration with various communities of practice that help knowledge accessibility and discovery.
- The resources for the editorial and management support of knowledge exchange platforms have a large share in the implementation and business model of online platforms that, when relying entirely on the resources of the transdisciplinary research projects, may influence the quality of the online content and ultimate knowledge exchange.
- A tailored overview of available knowledge can help accessibility to non-scientific audiences. Transdisciplinary projects can overcome barriers to sharing such tailored knowledge with the internal and external support of editorial and creative teams but require dedicated funding.

This study considered the researchers' and practitioners' perspectives from multiple disciplines, including representatives of societal organisations. However, the participants' management role was mainly limited to an advisory role. More participants were affiliated with a research institute or consultancy (13 interviews) than government and other stakeholder organisations (7 interviews). Therefore, future research should account for differences between management roles and stakeholder organisations. Regarding the number and variety of participants, the following study should also explore how best to continue the developed (online) collaborative platform for practitioners within and beyond the NCR Dutch community of practice. Moreover, the influence of improved access and sharing of online platforms on the reuse and applicability of transdisciplinary research knowledge is an aspect that also deserves further research.

CRediT authorship contribution statement

Vivian Juliette Cortes Arevalo: Conceptualisation, Methodology, Investigation, Formal analysis, Visualisation, Data Curation, Writing - Review & Editing. **Robert-Jan den Haan:** Conceptualisation, Methodology, Formal analysis, Writing - Review & Editing. **Koen D. Berends:** Conceptualisation, Methodology, Formal analysis, Writing - Review & Editing. **Fedor Baart:** Conceptualisation, Methodology, Writing - Review & Editing. **Mascha van der Voort:** Conceptualisation, Methodology, Writing - Review & Editing, Funding acquisition. **Suzanne J. M. H. Hulscher:** Conceptualisation, Methodology, Writing - Review & Editing, Funding acquisition.

Declaration of Competing Interest

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Data availability

The data that has been used is confidential.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.envsci.2023.06.009.

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