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CASE REPORT

Embedding futures studies in an applied water research program

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Abstract
The transition to a future-proof water system requires timely development of knowledge and innovation. Futures studies is essential for research programs to identify new opportunities and threats and allow for timely agenda setting. We present a case study where the approach of futures studies was embedded in an applied research program (Waterwijs) for drinking water utilities in the Netherlands and Flanders. Futures studies was organized in a structured program component called 'exploratory research' that combined concepts of foresight and horizon scanning, the knowledge pyramid, and a theory of change approach. The outcomes show that futures research was valuable for the research program and the drinking water utilities who are its clients. It enabled the achievement of long-term program goals such as the development of new technologies, fast response to emerging issues and informed the strategy of water utilities. Recommendations for the adoption of futures studies in Waterwijs and similar programs based on the experiences from this case include developing a culture of co-creation and trust, a clear structure and management, and a good strategy for stakeholder engagement and knowledge transfer.

Keywords Foresight · Horizon scanning · Knowledge transfer · Theory of change · Applied water research · Program management

Introduction

In a quickly changing world organizations need to be able to anticipate future challenges and opportunities to ensure timely preparation and adjustment of their strategies. Drinking water utilities in the Netherlands face the challenge of ensuring a safe and reliable drinking water supply in a changing environment with increasing pressures of climate change, emerging contaminants, population growth, and a complex stakeholder and governance constellation (Van Engelenburg et al. 2021). At the same time, drinking water production requires infrastructure with a long lifetime (>30 years) and very high capital investment. Water utilities therefore need to be aware of trends and potential future developments and risks. Luís et al. (2021) for example, demonstrated that a future-risk approach provides a valuable contribution to long-term strategic planning at a Portuguese water utility. The transition to a future-proof water system requires knowledge and innovation (Meijer 2007). Innovative and forward-looking solutions are needed to address the complex challenges of sustainability problems. There is an increasing need for impact-oriented knowledge development that addresses these societal challenges (Ramos-Vielba et al. 2018), and these knowledge systems need to strive towards salience, credibility and legitimacy of the information they produce in order to be most effective (Cash et al. 2003). This development and implementation of knowledge and solutions takes time and requires anticipation of future knowledge needs. It is therefore essential that research programs anticipate and prepare for future opportunities and threats.

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Futures studies is a research field that systematically studies possible futures, trends and developments. This helps increase the temporal extent (in e.g. months or years) of the foreseeable future and thereby provides valuable tools that enables research programs to anticipate and prepare for future developments and stay innovative and forward-looking. The methodologies developed within futures studies can be used to enable water utilities to better prepare for future opportunities and threats, and to set research agendas to better anticipate future knowledge needs (Segrave 2014). Within futures studies, foresight is defined as the systematic debate of complex futures that can be used to anticipate future opportunities and threats and identify objects in the present that are of importance to these possible futures (Cuhls 2020). It generally makes use of the method of horizon scanning; "the systematic tracking of pertinent developments that appear on the horizon in order to detect early signs of potentially important developments" (Cuhls 2020). The concepts and method of foresight and horizon scanning thus provide a framework to implement futures studies in practice (Cuhls 2020; Palomino et al. 2012). Horizon scanning is used for e.g. strategic planning, scenario planning, and to inform policy decisions for corporations and government agencies across different sectors and fields (Garnett et al. 2016; Luís et al. 2021; Rowe et al. 2017), as well as for identifying future research and policy developments in e.g. medicine and environmental science (Hines et al. 2019; Sutherland et al. 2024). However, there are few examples where horizon scanning has been integrated into research programs, and models for the successful integration and operationalization are still needed (Cuhls 2020).

Here, we present a case study that demonstrates how a futures studies approach was embedded into a multi-year applied transdisciplinary research program improving its relevance to the research beneficiaries. 'Waterwijs' (formerly BTO-Bedrijfstakonderzoek) is an applied research program for the Dutch, and one Flemish, drinking water utilities. The water sector faces complex challenges that create an increasing need for inter- and transdisciplinary (Brugnach and Özerol 2019) knowledge contributing to address societal challenges (Cuhls et al. 2024). Accordingly, the program has been designed with a strong societal impact focus (Brouwer et al. 2017; Munaretto et al. 2022). Systematic futures studies and horizon scanning has been embedded in the program since 2008. Refinements to the approach were made in the last 15 years based on practical experiences in the program as well as futures studies research and literature, which resulted in a structured research program component named the 'exploratory research'. The combined approaches of horizon scanning and foresight with a theory of change approach (Belcher and Halliwell 2021) and the knowledge pyramid of data—information – knowledge – wisdom (Rowley 2007) were used to operationalize the steps and interactions needed to enable systematic futures exploration, while contributing to the long-term goals of the Waterwijs program. This resulted in an approach based on building blocks from different bodies of literature (e.g. future studies, research impact, evaluation) to compose a unique method suitable for research programs with the ambition to achieve societal impact. We demonstrate how futures studies methodology was implemented and operationalized in practice in Waterwijs and combined with an impact-driven theory of change to design and implement a research program with a strong impact focus. After illustrating the approach (Section "Conceptual framework"), we demonstrate its value with illustration of different program outcomes (Section "Method"). The approach is then discussed in Section "Results", while Section "Discussion" presents lessons learned and recommendations for other contexts.

Conceptual framework

There is a long history of research on how the temporal extent of the goals, opportunities and threats that someone perceives relates to what motivates their decisions and actions that informed the development of the exploratory research (e.g. Cao et al. 2025; Lens 1986; Lens et al. 2012; Lewin 1942; Nuttin 2014). These psychological factors that play a role in individual decision making are augmented by factors that influence the decisions and actions of groups, such as the decision making style of the organisation (e.g. Sinnaiah et al. 2023; Jaradat et al. 2024). Different decision making processes and styles influence the uptake and outcomes of decisions building on strategic insights from exploratory research. There are different descriptive models of how such organizational decision making takes place, from more positivistic, rational models to more constructivist, intuitive and incremental models (e.g. Devi et al. 2020; Nikolic 2018). The exploratory research is built on the work of Palomino et al. (2012) and the literature on horizon scanning and sense making as described by Cuhls (2020) in particular. Palomino et al. (2012) presented a generalized method for horizon scanning for decision support. This framework was expanded upon and combined with the findings of Segrave (2014 and references therin) to include the necessary steps for sense making and research valorization (Fig. 1). Valorization here is defined according to Munaretto et al. (2022) as the process of generating impact from knowledge via continuous learning taking place within and between social learning structures (e.g. research projects and programs) where knowledge producers and users engage in productive interactions throughout the research

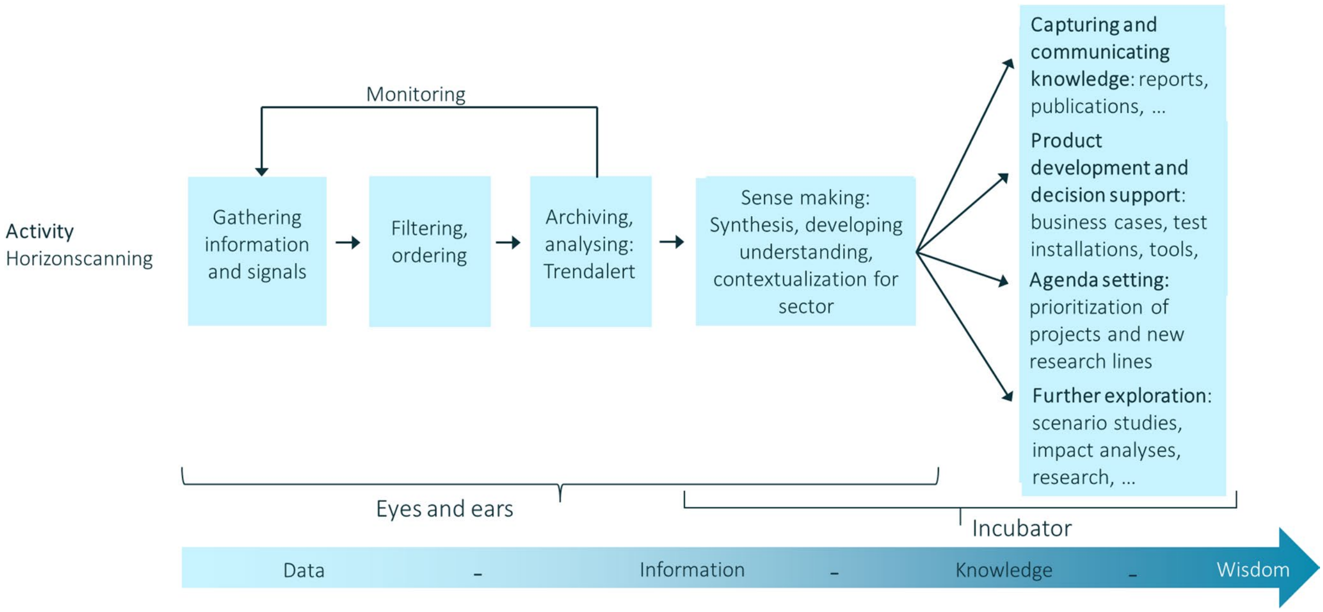

Fig. 1 Systematic method of the horizon scanning process, adjusted from Palomino et al., (2012). The activities are divided into 'eyes and ear' and 'incubator' projects reflecting their main function

process. During horizon scanning, signals from society and the scientific literature are gathered, filtered and prioritized.

In the Netherlands, 'strategic explorations' that include horizon scanning are carried out by national institutes such as the Directorate General for Public Works and Water Management (Rijkswaterstaat) and the Netherlands Environmental Assessment Agency (PBL). Hines et al. (2019) demonstrate that horizon scanning is a valuable tool in medical research and regulation, informing decision making at an organizational and international level. Sutherland et al. (2008) identify horizon scanning as an essential tool in environmental science to foresee emerging issues and be able to timely advise policy makers, and they lead an initiative to carry out an annual horizon scan of global biological conservation issues. A 10-year retrospective conducted in 2024 showed several issues identified 10 years earlier had indeed manifested the potential impact described (Sutherland et al. 2024). They stress that it is inherent to horizon scanning that some issues will never materialize because they were misjudged, because other circumstances intervened, or because their likelihood of occurrence was reduced by mitigation actions. A similar scan was carried out for forest management in the UK that stresses the need for forward-thinking in policy, practice and research, and to anticipate trends, opportunities and threats with regards to the major challenges expected to become relevant in the next 50 years (Tew et al. 2023).

Experts have an important role to translate the collected signal into knowledge and motivational objects for decision makers (Nuttin 1964). Segrave (2014) found that it is essential to consider who is involved in futures studies activities. They showed that the awareness and time horizon someone perceives correlates with their role in an organization, where the temporal extent of the goals, opportunities and threats that motivate the decisions and actions of operators tends to be shorter, while that of managers is longer and researchers tend to have the longest time horizons (Fig. 2, adapted from Segrave 2014). Researchers therefore have a responsibility to signal long-term threats and opportunities and translate them into objects that help motivate the decisions and actions of managers, decision makers and/or strategic advisors. The futures studies component of a research program should therefore ideally put researchers in the lead and allow them the time and resources to identify new signals of which the relevance and application may not be immediately clear (Segrave 2014). Recently, there is a movement to include a broader variety of perspectives and participants into the foresight process in transdisciplinary research settings (Cuhls et al. 2024; Schmidt et al. 2020). Within the Waterwijs research program these activities are covered in other parts of the program where agenda setting is carried out in co-creation with stakeholders.

The identified signals need to be assessed on their potential relevance for the sector and translated and communicated to the relevant persons who can use this knowledge to, for example, adjust a company strategy, develop risk mitigation for potential threats, or prepare for potential opportunities. This step of sense making and knowledge transfer is critical and complex, and reflects development of the knowledge pyramid from data to information and knowledge and eventually wisdom (Rowley 2007). It requires organization, filtering, prioritizing and analyzing signals,

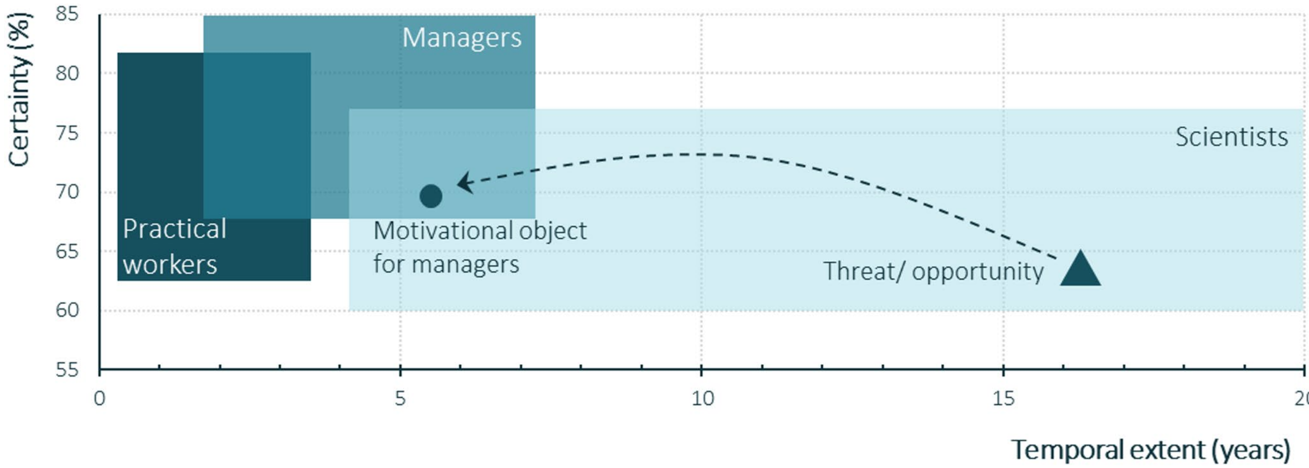

Fig. 2 The awareness of practical workers, managers and scientists across different temporal extents and levels of certainty, adapted from Segrave (2014)

as well as an awareness of scientific and societal context to identify their potential relevance and implications. This process is usually not linear and may require backtracking or making unexpected connections. Sufficient flexibility is needed to allow for this, while maintaining sufficient control of the process to ensure that all necessary steps are taken from information to knowledge (Fig. 1).

Method

Description of the case study

For the past 40 years, the Dutch drinking water utilities, and since 2018 one Flemish water utility, have collectively invested in an applied transdisciplinary research program called 'Waterwijs' (formerly 'Bedrijfstakonderzoek – BTO'), carried out by KWR Water Research Institute (KWR), to develop scientific knowledge, innovations and technology for a sustainable drinking water system. Waterwijs has the goal to develop relevant knowledge that is implemented in the practice of drinking water utilities, and used to support the decision-making process of drinking water utilities and relevant stakeholders (Brouwer et al. 2017; Munaretto et al. 2022). Since 2013, this research is organized in a transdisciplinary research program with a 6-year cycle and an investment of ca. 8.4 M€/year (in 2023). The functions of Waterwijs were defined together with the water utilities and used for the operationalization of the program. These include futures exploration, providing a knowledge basis and memory for the sector, connecting science and practice, decision support, collaboration and networking.

This case study describes how the function of futures exploration of Waterwijs was operationalized and carried out in a program component named 'exploratory research program' (hereafter referred to as 'exploratory research') in the Waterwijs program period 2018-2023. The exploratory research had a budget of ca. 0.9 M€/year in 2023, which represents approximately 10% of the total Waterwijs resources. The exploratory research includes horizon scanning and sense making, which are the first steps of foresight (Cuhls 2020) as well as the initial steps towards dissemination and valorization (Fig. 1). The early stages of activities connecting horizon scanning to scenario development and strategic planning are also part of the exploratory research. However, the subsequent, more detailed, activities of scenario development and strategic planning that are also considered part of foresight (Cuhls 2020) are usually transferred to other parts of the research organization more equipped for their execution or are taken up in bilateral contact with water utilities.

Futures studies and systematic horizon scanning for the Dutch water sector at KWR has been ongoing since 2008 and has to date signalled over 100 relevant trends for the sector (Frijns et al. 2012; Segrave et al. 2008). The Dutch Water Sector Intelligence platform (DWSI) is used to discuss the signalled trends with water professionals to develop understanding that can then be used for adaptive planning. The scientific basis and practical experience with this method at KWR has been expanded continuously since then, in particular with the work of Segrave (2014). For this study, we draw on the expertise and experience present at the institute in horizon scanning and futures studies, programme management and inter-and transdisciplinary research (ITD). We use insights from internal documentation such as reviews and annual reports, feedback and discussion from DWSI sessions, insights from individual project evaluations, and personal communication of the authors with KWR researchers and professionals from the water sector.

In the following sections we explain the organization and operationalization of the exploratory research. The results then present the outcomes from the program in the program-period 2018-2023. These are used to demonstrate its relevance and lessons learned.

Operationalization of impact pathways: from program function to outcomes

The conceptual underpinning of the exploratory research was operationalized into activities and impact pathways (Fig. 3) that combine the method of horizon scanning with a theory of change approach and the framework of the data-information-knowledge-wisdom (DIKW) pyramid. The horizontal axis of Fig. 3 shows the main steps of horizon scanning and future exploration in the development from data to information and knowledge. The vertical axis indicates the impact pathways from activity and output to the desired outcomes and eventual impact. Together, this figure demonstrates the interlinkage of steps that need to take place to fulfill the functions of the exploratory research within the overall Waterwijs program. These functions guided the definition of two long-term outcomes for the exploratory research: (1) The strategic plans of water companies are underpinned by the latest knowledge, tools and signals about future developments. (2) The research agenda of the Waterwijs program is forward looking and provides utilities with relevant knowledge. Each of these functions has an impact pathway defined for both the water utilities (users of the knowledge), and for the researchers and program managers (co-creators with the utilities of the knowledge) within Waterwijs. These impact pathways are used to define program management activities and research projects. For successful future exploration, it is necessary that the steps outlined in the impact pathways are followed consistently, that the appropriate experts and stakeholders are involved, and that feedback and iteration between them can take place.

Operationalization of research activities into projects

All activities in the exploratory research program are organized into smaller projects, with an annual budget reserved for coordination and program management. Projects are defined based on their main activities. An organizational distinction was made by the program management between two types of projects that allow for different expected outcomes. 'Eyes and ears' projects are used to carry out horizon scanning activities and the first steps towards sense making with the aim of identifying new trends and developments and interpreting their significance for the water sector. 'Incubator' projects are used to carry out a more in-depth investigation for sense making and meaning giving and explore, test, or further develop new concepts related to such investigations. Within the 'eyes and ears' and 'incubator' projects, a distinction is made based on the intended audience. The aim is for water utilities to use the outcomes of the exploratory research to inform their operations and strategy. In addition, the exploratory research also has a valuable function within the Waterwijs program and for the research organization to innovate and identify new research questions. Outcomes from the program are often of interest to both groups. The research organization is in the lead for the exploratory research according to the recommendations of Segrave (2014). Projects are carried out by researchers and have a specified output that contributes to the desired outcomes and impact.

Next to the process of futures exploration, the thematic breadth of the explorations has to be considered. Water utilities have domain-specific knowledge demands that originate in the need to ensure a robust water supply and optimal operation of their facilities. For example, developing novel testing methods to ensure the microbial safety of drinking water, or modelling optimal maintenance and replacement of pipelines. Next to domain specific knowledge demands, water utilities also have to anticipate broader external developments of, for example, population growth, political and economic developments, or environmental concerns (Aguilar 1967). Horizon scanning distinguishes itself by its wide scope across disciplinary and departmental borders (van Rij 2010). A futures research program should therefore both address these disciplinary (thematic) knowledge demands, as well as signal broader opportunities and threats. The exploratory research therefor includes both 'thematic' explorations that connect to the disciplinary knowledge developed in Waterwijs, as well as 'integrative' explorations that consider broader developments in society. This leads to a quadrant of four types of projects within the exploratory research (Fig. 4) where the x-axis indicates the depth of the exploration and the y-axis indicates the thematic breadth of the exploration.

Expected outputs and outcomes of the exploratory research program

The expected output of projects is based on their function in the program. Horizon scanning is carried out by subject matter experts for each research theme in the Waterwijs program, as well as by a dedicated generalist team of experts in futures studies. For the integrative/generalist explorations, horizon scanning is carried out in a systematic way along the so-called SEPTED dimensions (Socio-cultural, Economy, Political, Technology, Ecology, Demography). These dimensions are intended to help horizon scanners

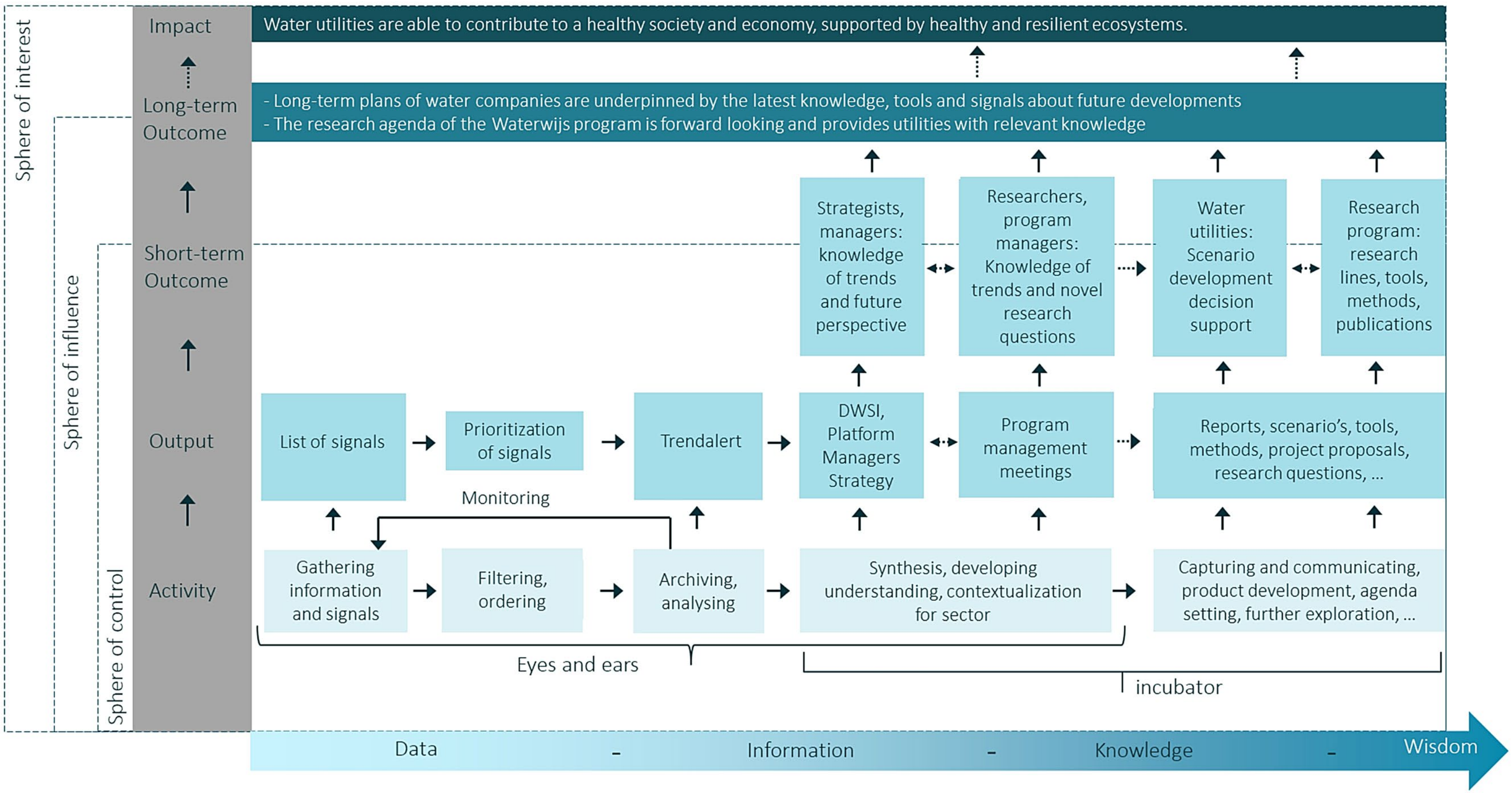

Fig. 3 Projected impact pathway of the exploratory research, based on the activities, output and expected outcomes. DWSI indicates the Dutch Water Sector Intelligence

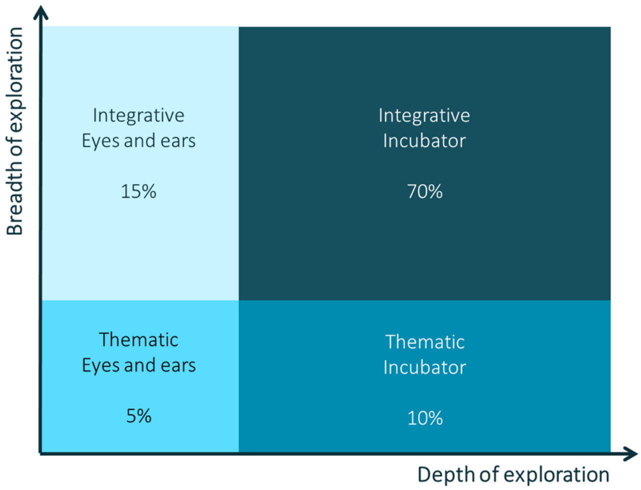

Fig. 4 Depth vs. breadth quadrant of the type of projects in the exploratory research. The percentages refer to the relative amount of resources allocated to each quadrant of projects

limit their blind spots and broaden their scope while following a structured approach (Cuhls 2020), though no strict definition is used and similar frameworks such as PESTLE may be equally suitable (Andersen, preprint). Each year, a number of trends are selected for analysis. The choice of which trends to explore further is made in conversation between the subject matter experts and the lead future studies experts taking into account the various attributes of the trends, such as potential impact, the level of (un)certainty, and ambiguity about the meaning and/or the desirability of the (anticipated) changes. These conversations ensure that the broader scope of the cross-disciplinary, generalist horizon scanning is combined with the deeper knowledge and more specific focus of the experts, maximizing the benefits of expert knowledge while limiting the risks of blind-spots. A short report (a so-called 'trend alert ') is written describing the trend and its potential relevance for the water sector. Trend alerts are written in an attractive visual format and accessible language that can be easily shared with stakeholders of different backgrounds. As recommended by Garnett et al. (2016) each trend alert contains a small table that gives a qualitative overview (low, medium, high) of the likelihood of a trend occurring, and the magnitude of its potential impact, and it's potential implications for the sector are summarized. Trend alerts are used in the DWSI platform in sessions with strategists and policy advisors at drinking water utilities and water boards (Dutch authorities responsible for flood protection, regional water management and treatment of urban wastewater). DWSI uses concepts of social learning to ensure knowledge transfer takes place, and to further discuss and interpret the potential meaning for the water sector (Frijns et al. 2012). Horizon scanning and the resulting trend alerts are also intended to increase awareness of novel trends, developments and research questions for researchers and program managers in the Waterwijs program, and used for research agenda setting for 'incubator' projects within the exploratory research as well as in other parts of the research program.

'Incubator' projects provide a place in the research program with space for researchers to explore and test out new concepts. 'Thematic incubator' projects are carried out and led by subject matter experts who have the best awareness of the knowledge needs of stakeholders in their particular field. This ensures a close connection to other research projects within the theme. 'Integrative incubator' projects are independent from the other parts of the program. The research organization made a strategic choice to use this space to encourage interdisciplinarity and collaboration across research themes. Project teams are composed of researchers from different disciplines depending on the research question and they are strongly encouraged to include collaboration of researchers with different backgrounds.

Due to their function, the output and outcomes of 'incubator' projects are more concrete but also more diverse than the 'eyes and ears' projects. The aim of these project is to explore the meaning of a given topic, making sense, and understanding the implications of a development, or to prepare for and work towards further implementation. Expected outputs are (1) reports, publications and/or presentations, (2) early development of products, tools, decision support, test installations, proof of concepts, or exploration of business cases, (3) research proposals or prioritization of research lines, (4) exploration in scenario studies, impact analyses, or further research.

The intended time horizon for exploratory research projects to achieve their impact is 5-10 years. The outcomes from individual projects are often indirect and not immediately clear. General desired outcomes of the exploratory research program (as identified in the program Theory of Change) are: agenda setting and follow-up research, insight into the meaning of developments for the water sector, awareness of relevant trends for policy discussions, strengthening scientific development, or a justified decision not to follow up an exploration. To monitor these outcomes, project leaders report annually if any of these points were achieved for their project. An idealized trajectory within the exploratory research would be for an emerging topic to be signaled via horizon scanning, and then prioritized for an incubator project in which scientific understanding is increased, a proof of concept is developed and follow-up opportunities are identified, to then be added to the research agenda of the other parts of Waterwijs, and eventually applied in practice or integrated into the strategy of a drinking water utility. In practice, this development will often be indirect and/or interspersed with developments outside the program.

Knowledge transfer

The output from the exploratory research needs to be translated into awareness and knowledge for stakeholders in the sector and the research program upon which actions can be taken, and decisions can be made. To achieve the long-term outcomes knowledge transfer needs to take place both with the water utilities and between scientists and program managers within the research program (Fig. 3). For effective knowledge transfer, it is essential that people at the right level of the organization are reached. The DWSI network is the main channel for knowledge transfer to the water utilities and water boards and involves people at a strategic level of the organizations. Managers and strategy advisors are the main audience for trend alerts as they can use this knowledge to anticipate and prepare for future opportunities and threats for their organization. Building on the experience gained through horizon scanning, DWSI provides a platform and method for active co-learning between strategic advisors from the various organizations. Facilitating social learning in this way generates new knowledge, beyond that which is provided through the research program. Knowledge transfer with water utilities also takes place along the channels of collaboration and co-creation in the Waterwijs research program. Within the research organization, knowledge transfer takes place via planned dissemination meetings and informal interactions between researchers. While planned dissemination meetings can reach a broader audience of colleagues (again the responsibility to act to stay informed, i.e. to join the meeting, falls on the researcher), informal interactions tend to remain confined among existing professional relationships which may not necessarily be the right audience for the specific knowledge being shared.

Results

Overview of different types of outcomes from the exploratory research program 2018-2023

Between 2018 and 2023, 74 trend alerts were written and shared, and 35 thematic and 26 integrative incubator projects were carried out. The outputs from incubator projects are diverse and depend on the research question and methodology used. These consist of reports, methodologies, proof of concepts, project proposals and/or strategies for follow up, etc., but can also include networking, identification of strategic partners and/or advocates for agenda setting. Project results were also used to support policy discussions on a variety of topics by providing knowledge and raising awareness. Where suitable to the research question, water utilities were directly involved in projects.

In a few cases, the choice was made not to follow up a topic. A substantiated decision not to pursue a topic is a successful outcome of an exploratory research project. Exploratory research includes the possibility to take risks and explore topics for which the potential application is not yet certain. For example, a previously published extraction method for bacteriophages proved not to be reproducible (van der Wielen 2023). In another case, a promising data mining method proved not to be applicable due to limitations in the quality and lack of standardization of data in the available literature (Pronk et al. 2024). The knowledge of, for example, which methods cannot be successfully applied is valuable for the researchers and the scientific community, despite the project not having follow up.

Monitoring the longer-term outcomes and impact from the program is challenging. It is time intensive and involves a large number of different experts and a large variety of topics. Outcomes are often indirect and may not be attributed to the initial signaling of a trend or output from an exploratory project. We identified four examples related to the intended long-term outcomes of the exploratory research (Fig. 2) and illustrate how these outcomes were achieved. With respect to long-term outcome (1) “long-term plans of water companies are underpinned by the latest knowledge, tools and signals about future developments”, we discuss how water utilities use trend alerts for their strategy and innovation agenda. With respect to long-term outcome (2) “the research agenda of the Waterwijs program is forward looking and provides utilities with relevant knowledge”, we provide examples on the follow-up from trend alerts and research agenda setting. Lastly, we share an example of how the exploratory research contributed to enabling the Dutch water sector to address emerging societal challenges, thereby contributing directly to the intended impact of the Waterwijs program, i.e. “Water utilities are able to contribute to a healthy society and economy, supported by healthy and resilient ecosystems”. In each case, a short summary of the societal development is given and the main insights are discussed.

Water utilities use trend alerts for strategy and innovation agenda

Trend alerts are continuously made available via the program intranet site. Strategists and advisors at the water companies use trend alerts depending on their own planning cycle and needs for outside input. In DWSI, trend alerts are shared and discussed with strategists from various types of organizations (e.g. drinking water companies, water authorities) throughout the Dutch water sector. The trend alerts have been used by individual water companies as input for research agendas, innovation programs and strategy development, but also, for example, for adjusting the 'corporate social responsibility' policy. The trend alerts are collected centrally and remain available. There are trends from 10-20 years ago that are particularly topical and relevant today. For example, "Raw material use, prices and scarcity", "Political plans & biodiversity", and "Antibiotic resistance" from 2011, and "Epidemics of the twenty-first century" from 2012 with a scenario including the corona virus. Similarly, current trend alerts can become relevant in the future. Examples of topics that have informed strategy and innovation agenda of water utilities include integrative trends on e.g. 'A World in Uncertainty' on international geopolitical relations and their implications for water supply from 2013, and more technical developments of e.g. artificial intelligence and robotics and deep learning (van Alphen and Segrave 2016; Tian et al. 2022).

Our experiences show that horizon scanning and the resulting trend alerts are valuable for utilities to inform their strategy. For example, following the trend alert "Activist investors and environmental lawsuits" from 2018 strategists at several water companies further investigated the opportunities for employing more legal routes to achieving their goals. Trend alerts have also been used to check for preparedness for emerging challenges following the logic of 'what if' scenarios to test the robustness of solutions. However, it is essential to ensure knowledge transfer takes place at the right levels in the organization. The DWSI network and method (Frijns et al. 2012) was essential in the success of this approach. The method requires building patience and trust on the part of the client as the relevance of signaled trends may not immediately be clear. The DWSI community must also feel safe in sharing their strategic challenges with peer professionals from other organisations.

Follow-up from trend alerts—next generation sequencing

Next generation sequencing was first signaled in 2015/2016 as a possible tool for fast detection of fecal contamination of water. At that time it was concluded that priority would be given to other methods (such as RT-PCR), but that next generation sequencing was a promising tool for the future (Heijnen 2016). A trend alert in 2018 again signaled its potential. The methodology was seen as promising but required further optimization of the technology before it could become implemented (Heijnen 2018). This was followed up with an incubator project in 2019, in which a commercial tool (MinION) was tested. Although the potential application was clear, the accuracy and reliability was not yet sufficient at that time (Heijnen 2019). In 2023, a target enrichment for molecular analyses was signaled as yielding less complex data, which simplifies the bioinformatical analyses needed to interpret the results (van Charante and Heijnen 2023). This development resolved some of the barriers towards implementation of next generation sequencing and brought it closer to practice. The trend alert was followed by a project started in 2024 together with drinking water utilities that aims to develop a roadmap towards using next generation sequencing in practice for monitoring microbial drinking water quality (currently ongoing).

This example demonstrates how the development of a trend is followed until it is ready to be taken up in the implementation-oriented parts of the research program. The time between the first signal and eventual agenda setting is 8-9 years, which fits with the time horizon of the exploratory research. The development here is mostly driven by external factors such as the rise and fast development in the field of metagenomics. A number of success factors within the research program can be identified. Firstly, a motivated expert was present in the research organization, who was willing and interested to explore emerging technologies in their field and come back to them when they were not successful the first time. There was a willingness and possibility to take a risk and at first conclude that technology was not yet ready for implementation. Lastly, futures researchers kept an archive of previous signaled trends and could remind researchers to come back to a topic that was signaled a long time ago. This last point also emphasizes the function of the Waterwijs research program as an institutional memory and knowledge basis for the sector. Next to this, the topic of next-generation sequencing is an example of combining the broader scope of the cross-disciplinary, generalist horizon scanning, which signaled the mega-trend of NBIC-convergence (Nano-, Bio-, Info-, Cognitive technologies) with the deeper knowledge and more specific focus of the experts (next generation sequencing specifically). Funding was made available for this topic by program managers, particularly because it was signaled by both types of researchers.

Research agenda setting—area-oriented management

A number of integrative incubator projects between 2018 - 2023 focused on collaborations between social sciences and technology, which enabled the development and agenda setting of new knowledge domains. Several trend signals in the period 2018-2023 highlighted the need for drinking water utilities to develop new, transformative approaches to collaborate and coordinate initiatives with stakeholders in their region against the backdrop of major changes in society. In 2023, an incubator project was carried out on transformative regional environment management at drinking water utilities. This project made and inventory of the approaches drinking water utilities use to interact and manage relations with stakeholders in their environment and identified concepts and knowledge from the scientific literature on transition management that could help utilities initiate transformative change to solve environmental and societal challenges facing water utilities. A contact group was initiated with stakeholders from water utilities that highlighted the need for follow-up research. This led to the definition of a major research theme on area-oriented management in the Waterwijs-program period 2024-2029.

The exploratory research project provided a valuable knowledge basis that was needed to initiate and support the discussions with water professionals on this topic, and to frame the challenges and knowledge needs. It provided the space for experimentation and exploration of this emerging topic, and allowed researchers to build expertise and experience, which enabled the agenda setting of new research lines for the overall research program.

Fast response to emerging societal challenges—wastewater based epidemiology

In May 2020 at the start of the Covid-19 pandemic, Medema et al. (2020) published a landmark paper that reported how detection of the SARS-Coronavirus in sewage (sewage surveillance) could be used as an early warning system to monitor the spread of the virus in the population. This method has since then been implemented in many countries across the world, and the lead researcher has been awarded the Lee Kuan Yew Water Prize 2024. Though this work is the culmination of many years of research, some critical links to the exploratory research are present. Already in 2012, the possibility of a pandemic, and possible response strategies were discussed in a DWSI session. The concept of wastewater-based epidemiology and its potential applications were signaled in 2018 and lead to an incubator project exploring its potential (Steenbeek 2020). This research focused on its use in monitoring the spread of antibiotic resistance (Steenbeek et al. 2022), but the experience and methodology could quickly be adapted for sewage surveillance of Covid-19.

This example demonstrates that the exploratory research enabled a fast response to emerging societal challenges and emergencies. The shift from antibiotic resistance to Covid-19 illustrates the difficulty to predict how and when a topic may become relevant. Lastly, the connection to ongoing academic research is essential to ensure that research builds on and is connected with the latest knowledge and leading experts in the field (Medema is a university professor and works at the research organization).

Discussion

This case study demonstrates how the concepts of horizon scanning and foresight can be operationalized and implemented in practice in Waterwijs. We presented the conceptual foundation, showed the method from design to operationalization and implementation and provided examples of the program outcomes. The experiences from the exploratory research demonstrate that this method provides an effective way for the water utilities to prepare for the future, and for the overall Waterwijs research program to renew itself and stay innovative. The examples provided illustrate the ways in which the long-term outcomes of the exploratory research (Fig. 3) are achieved. According to the program evaluation in 2021 (Munaretto et al. 2022) and ongoing reflection with clients, the exploratory research helps inform the long-term plans of water utilities and has contributed to setting an innovative and forward-looking research agenda for the Waterwijs program. The exploratory research is recognized as valuable by its stakeholders and provides an example of how this method can be implemented in other research programs.

The approach and structure of the exploratory research was developed to specifically fit the needs and culture of the Waterwijs research program. Below we reflect on the factors that contribute to the success of the exploratory research program within Waterwijs as well as its challenges, and in the next section we provide recommendations and learning points for the implementation of similar approaches in other applied research programs. Firstly, Waterwijs is built on a long-standing culture of collectiveness, collaboration and co-creation (Brouwer et al. 2017; Munaretto et al. 2022). This enables a research culture where there is a willingness to share information and work towards a joint goal as well as a high level of trust between researchers and the client. Horizon scanning and foresight comes with a lot of uncertainty as the outcomes and relevance of exploratory research are not immediately apparent. This means clients need to rely on the research organization to ensure the program keeps fulfilling its goal, which requires trust between the clients and the research organization. Trust however is not sufficient. There is a need to build credibility in the horizon scanning process by clearly communicating its limitations and the likelihood and potential impact of signalled trends (Garnett et al. 2016; Schultz 2006; Sutherland et al. 2008). At the same time, researchers need to have the freedom and resources to explore, scan for new trends and develop new ideas. This includes the possibility to take risk and accept (both clients and researchers) that not every project will have outcomes that lead to clear follow-up actions. Finally, the method is complex and involves multiple stakeholders and researchers from different disciplines and backgrounds who are not familiar with the concepts and methodologies of futures studies. Therefore, domain experts need the support of futures studies experts who guides the process of horizon scanning and to provides critical reflection. Adequate coordination and program management is needed to maintain the overall goals, set boundaries and justify the method to clients. These conditions require commitment at the management level of the research program to ensure its long-term success.

In the last several years there have been major developments in the use and integration of big data, machine learning and large language models into horizon scanning (e.g. Cuhls et al. 2024; Muraro and Salles-Filho 2024). Future development of the program should explore possibilities for integration of these technologies into the exploratory research program, although it is essential to also consider its challenges and limitations (Muraro and Salles-Filho 2024).

It is important that horizon scanning and foresight is actively used and discussed in order to maintain an efficient flow of information (Cuhls 2020). This requires a well-defined approach for knowledge transfer. As the impact pathways of the exploratory research demonstrate (Fig. 3), a number of consecutive steps are needed in the process of horizon scanning and in the transfer of knowledge to achieve the project outcomes. These steps may involve several different people with different expertise and roles in the organization. Clear structure and understanding by all participants of their own role and of expectations are needed to effectively go through the steps of horizon scanning, and to ensure that signals are followed up and communicated to stakeholders. The outcomes from future studies are uncertain and usually qualitative. It needs to be clearly communicated what the implications and limitations of trend signals are to ensure continued credibility of the program (Garnett et al. 2016).

Hines et al. (2019) noted that horizon scanning reports rarely fed directly into policy making. In part, this can be explained by the unpredictable nature and longer time scale of horizon scanning. They further indicate that credibility and authority are required to influence policy making (Hines et al. 2019). Productive interactions for knowledge transfer require a clear view of both the specific audience the knowledge is for, the specific information they need, and the potential actions they can take based on this (Spaapen and van Drooge 2011). It is essential to involve people at the right level of the organisation who have an interest in the findings of futures study and the ability to act on this knowledge in their organization. Next to that, in our experience time and effort are needed to develop understanding and trust in the process, as well as a strict quality control on the program outputs. Signals that are relatively far in the future need to be translated into motivational objects (potential actions, decisions, tools, etc.) within the relevant time perspective of the target audience and communicated clearly (Segrave 2014). To achieve this, a format was developed for trend alerts that delivers the information and potential impact in a concise, consistent and accessible way. In addition, various engagement methods are used during DWSI sessions to enable social learning. Overall, a tailored approach is needed for an optimal knowledge transfer. As highlighted by Cuhls (2020) a major challenge still remains to ensure effective knowledge transfer is achieved with limited resources and time availability, and to hold the attention of stakeholders amidst a flood of information.

Gharedaghi (1999) defines spheres of influence in which an organization can have different levels of control. When applied to the impact pathways of the exploratory research (Fig. 3), the activities and output, and to some extent the short-term outcomes are within the sphere of control of the exploratory research program. Long-term outcomes are in the sphere of influence. Here, stakeholders and managers in the research organization and at the water utilities share and advocate for the outcomes exploratory research to be taken up. Finally, though the exploratory research aims to have impact on the contribution to a healthy society and economy, supported by healthy and resilient ecosystems (sphere of interest), there is little control on how this is achieved. The impact pathways (Fig. 3) help identify the essential steps that are needed to create the optimal conditions to achieve this impact. It can be used as a tool to assess if the program is functioning properly, and visualize to participants and managers how the activities are linked and contribute to the overall goals.

Outcomes from the exploratory research can take a long time to develop and are often indirect (i.e. via various other projects and initiatives), meaning that exploratory research output may not be directly credited. It is therefore challenging to gain a complete overview of the effects of the program. The examples in Section "Method" provide an illustration. Further research is needed on how the long-term program outcomes can best be monitored (Belcher and Halliwell 2021; Belcher and Hughes 2020). Next steps include a systematic assessment of the steps and underlying assumptions of the impact pathways for the exploratory research (Fig. 3) to identify critical points for improvement. However, an assessment of the program period 2018-2023 showed that the program fulfilled its goals (van Dam et al. 2024).

Next to the direct outputs and outcomes from the program we may reflect from experience on the indirect benefits the exploratory research provides for the research organization, and thereby the research program. Horizon scanning and exploratory research can create a 'play space' and environment for experimentation where there is room for creativity and for researchers to grow and develop new skills. This helps create a positive atmosphere where new ideas and initiatives emerge, especially when this is encouraged by strategic decisions in the management of the organization and the program.

Conclusions and recommendations

This research presents a method for how horizon scanning and foresight can be designed, operationalized and implemented within applied research programs by combining concepts from futures studies, theory of change and the knowledge pyramid. Specifically, the Waterwijs exploratory research of the Dutch and Flemish drinking water sector demonstrated how exploratory research contributes to integrating new societal and technological developments into research lines and agenda setting of new topics, and how it enables fast response to urgent emerging challenges. The research program clients, i.e. the water utilities, use trend alerts developed by exploratory research for their own company strategy and innovation agenda.

We demonstrate the value of systematic horizon scanning and foresight for research and innovation programs to be able to anticipate future developments and ensure that the program stays innovative and salient. The implementation of a systematic approach helps ensure that dedicated time is given to futures exploration. Based on the case experiences, we recommend considering the following points when implementing a futures studies approach in similar applied research programs:

(1) Exploratory research works best when embedded in a research culture of collectiveness, collaboration and co-creation (pre-condition for success). This includes:

- o Taking time to implement activities for building trust and credibility between the research organisation and end-users of the results;
- o Ensuring understanding of the possibilities and limitations of futures studies, and the ability to communicate this to stakeholders;

(2) Adequate program management including:

- o Ensuring coordination, management and quality control of exploratory research products;
- o Ensure a link between the output of exploratory research and follow-up activities of foresight such as scenario development and strategic planning.

(3) Stakeholder management and knowledge transfer:

- o Identify and engage key end-users of exploratory research findings at the appropriate organizational level, ensuring they have the capacity to act on trend signals effectively;
- o Embed structured methods for knowledge transfer into the program that include well written output (reports, trend alerts) and clearly state their potential relevance to the client, as well as the facilitation of knowledge transfer in workshops and/or social learning sessions.

Current research within the Waterwijs program is focused on how to further enhance its outcomes and impact. On this point, a major scientific questions on how to effectively manage knowledge transfer remains open for this program and has relevance to applied research programs in general. The exploratory research has a large and diverse number of stakeholders. What can we expect to achieve, and how can we reach a broader audience with stakeholders and within the research organization? In addition, there is a need to develop monitoring and evaluation approaches that demonstrate the outcomes of research programs at a longer timescale, as well as evaluation approaches that serve learning purposes besides demonstrating the continuous value of the program for clients.

The exploratory research program was designed to fit the Waterwijs research program and developed in close synergy with other activities and program components. The specific needs and context need to be considered when implementing this approach in a different organization. However, we believe this case study provides inspiration for other organizations and research programs. It is an essential tool to help us keep looking beyond the urgent topics of the day that draw our attention. In a quickly changing world it is necessary to reserve time to think about potential future opportunities and threats and how we prepare for them.

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