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Mobilising academic research for transformative change

A case study on the influence of a mission-driven knowledge ecosystem on the credibility cycle of an academic researcher



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Abstract

In order to face the societal challenges of today and tomorrow, governments look for innovations that could help in solving these challenges. In recent years a third frame on these governmental policies has been formed, namely transformative policy. This study examines a mission-driven knowledge ecosystem (KES) as an example of how knowledge can be organised for transformative change. It is researched what the influence of such a mission-driven KES is on the credibility cycle of an academic PhD researcher. This results in the following research question: *What is the influence of a mission-driven knowledge ecosystem on the credibility cycle of an academic researcher?*

Literature on directionality, KESs and the credibility cycle is used to answer this research question. The concept of directionality is used to explain how they play a role in a mission-driven KES. Literature on KES is used to form a framework that can be used to study a mission-driven KES. Lastly, literature on the credibility cycle is used to study the research process of a researcher.

A case study was carried out on the mission-driven KES on CATO. CATO was organised around Carbon Capture and Storage (CCS) knowledge, ranging from technical knowledge of the technology to public perception of CCS. A document analysis was carried out to study this mission-driven KES and interviews were done with PhD researchers, supervisors, coordinators and the director to get insights into PhD research in CATO.

CATO had several mechanisms and characteristics of a mission-driven KES. There was a group of heterogenous actors working together in a social network to formulate new knowledge in the field of CCS. PhD researchers encountered actors from industry or researchers from other disciplines they would normally not interact with. This resulted in research that was aligned with the mission of the ecosystem and collaboration was induced. Furthermore, the credibility cycle of PhD researchers changed to a credibility cycle which was, next to the academic needs, also focused on societal and industrial needs.

All in all, a mission-driven KES significantly influences the credibility cycle of a PhD researcher. However, it must be closely monitored if the goal and mission of the KES are truly beneficial for society. In the case of CATO the role of industrial incumbents was more significant than the role of NGOs. The public controversy around CCS shows the importance of the involvement of NGOs and society in the formation of a mission-driven KES.

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Introduction

Society faces grand challenges in the coming years, such as preventing climate change, reducing poverty and gender inequality. The United Nations categorised all these challenges in the so-called Sustainable Development Goals (SDGs) (United Nations, 2015). Governments see the uptake of innovations as a solution to these grand challenges. The usage of innovations in the sustainable domain can help in reducing carbon emissions.

Over the past century, several frames have been formed on governmental policy for innovations (Schot & Steinmueller, 2018). The first framing was articulated after the second world war and was solely focused on market failures, which could be addressed by supporting science and R&D. The second framing was formulated in the 1980s and was, next to market failures, focused on system failures as well. National systems of innovation became important, and policy became more targeted at building links between elements in the system. The most recent third framing, transformative change, has a broader societal focus than the two preceding frames and is focused on transformative innovation policy (Weber & Rohracher, 2012). Concepts such as wickedness, temporality and directionality are important in this third frame (Schot & Steinmueller, 2018). In this study, we study the concept of directionality. Directionality is needed for transformative change and describes the importance of setting collective priorities.

The role of scientific knowledge is still underdeveloped in the third frame. The usage, mobilisation, and organisation of scientific knowledge in transformative change are still seen as a "black box" and therefore need explorative research (van Oost et al., 2016). More importantly, scientific knowledge is critical to tackling specific scientific barriers and, ultimately, the key to addressing grand societal challenges and missions (Petit, 2004). However, it is still unclear what the precise role can be and how to mobilise and organise researchers' scientific knowledge (D'Este et al., 2018).

To get new insight into the role of researchers' scientific knowledge in the third frame. The framework of a mission-driven knowledge ecosystem (KES) and the credibility cycle are used. A mission-driven KES describes how knowledge production can be organised around a particular societal mission, which may provide directionality (Järvi et al., 2018) (Schot and Steinmueller, 2018b). The credibility cycle describes the knowledge production process of researchers (L. Hessels et al., 2009). These two frameworks can help explain how a scientific researcher operates in a transformative environment. In this way, it may become clear how the directionality of a mission-driven KES can impact the scientific work of researchers and the researchers themselves. This results in the following research question:

What is the influence of a mission-driven knowledge ecosystem on the credibility cycle of an academic researcher?

A case study was carried out to research how certain dynamics between scientific knowledge and a mission-driven knowledge ecosystem play out in an empirical setting. This calls for a case that is situated in a complex environment with a societal problem at hand. Moreover, scientific knowledge must be a vital factor for the ecosystem. The case of Carbon, Capture and Storage (CCS) and the research programme CATO in the Netherlands matches these requirements. Scientific knowledge, such as fundamental knowledge, is seen as an essential source for new scientific breakthroughs in capturing and storing CO2 (Van Egmond et al., 2012).

Moreover, a complex societal problem is at hand in the case of CCS. Certain scholars and societal groups see CCS as vital in reducing carbon emissions. In contrast, other scholars and societal groups see it as a way to sustain the current polluting system (Stephens, 2015). This 'extreme' case might show interesting dynamics for a mission-driven KES in the sense of contradicting societal statements and different directions. It may explain, for example, how directionality can help mobilise scientific researchers for a goal that scientific researchers would not work on. Finally, the case of CATO has a diverse set of organisations in the ecosystem, a vital characteristic of a KES (Van Egmond et al., 2012) (Järvi et al., 2018). Overall, the mission-driven KES of CATO in the Netherlands might give new insights into the influence of a mission-driven KES on participating scientific researchers.

At this moment in time, the relationship between academic research and societal missions in the context of a KES has yet to be researched (van Oost et al., 2016). This study tries to get new insights into the literature on KES by providing empirical evidence of a mission-driven KES (Suominen et al., 2019). Literature on KES is still underdeveloped, and this research might provide new insights or prove current schools of thought (Suominen et al., 2019). Furthermore, literature on the credibility cycle is provided with new insights on the workings of the credibility cycle in an another kind of setting, such as a missiondriven KES. This also adds to the literature of Hessels et al. (2009) on the relevance of scientific research and the changing contract between science and society. Lastly, the literature on transformative policy is expanded upon by showing how societal missions can be addressed by KESs and by explaining the "black box" of scientific knowledge production (van Oost et al., 2016). This research tries to formulate and conceptualise dynamics in a mission-driven KES by combining related literature blocks and giving the concepts more empirical evidence.

The grand societal challenges that the world is facing are complex and require solving. A promising way of looking at this is transformative innovation policy (Schot and Steinmueller, 2018). This study expands on the work on transformative innovation policy by explaining the role of scientific knowledge and how it may be mobilised for societal missions and societal value. Moreover, this study may benefit policymakers in the knowledge domain, looking for ways to use scientific knowledge for societal challenges. Furthermore, it shows how a mission-driven KES can help organise scientific knowledge for societal challenges. Current policy measures are focusing on such KESs and therefore this study may be beneficial by giving empirical evidence of such ecosystems (Rijksoverheid, 2020). Lastly, this study may be beneficial for the case of CCS in the Netherlands. It might become clear what kind of dynamics are at play in this case, which can be used to improve knowledge development and sharing for CCS in the Netherlands.

This thesis is structured as follows. The first section describes the theoretical framework of this study. In the second section, the methodology will be explained. In the third section, the results will be discussed. In the fourth section, a discussion will be given, and a conclusion will be given in the final section.

Theoretical framework

In this section, the theoretical framework of this thesis is elaborated upon. First, it is shown how all three theory parts are connected in the theoretical framework. Then, the three different theories are elaborated upon. Finally, a synthesis is given of the three different theoretical parts of this study.

In this research, we study how an individual researcher is influenced by working in an environment working towards increasing knowledge for a societal mission. A case study was carried out on such an environment, namely CATO. We studied how individual researchers were influenced by doing their research work in such an environment. This shows that the study has two distinct parts that must be researched: the programme of CATO and the individual researcher working in the programme. The first part is researched with the theoretical lens of a knowledge ecosystem. Literature on knowledge ecosystems provides an understanding of how such cooperations work and what dynamics are essential to study when knowledge is created and shared between heterogeneous actors. The second part is researched with the theoretical lens of the credibility cycle. Literature on the credibility cycle describes the research process of an individual researcher. It shows how the research process may change due to participating in a knowledge ecosystem. Lastly, the concept of directionality was used to explain the usage of a mission for such a knowledge ecosystem and how this influences the individual researcher. All in all, literature on directionality and knowledge ecosystems was used to provide an understanding of CATO and literature on the credibility cycle was used to provide an understanding of the individual researcher in such a mission-driven KES. Figure 1 provides an overview of this theoretical framework. In which you can see we examine what the influence of a mission-driven KES (CATO) is on the credibility cycle (individual researcher).



Figure 1, theoretical framework

Other scholars have yet to carry out the combination of the three different theories. It is, therefore, essential to show that the different theories each serve their goal of answering the research question. First, it will be explained what directionality means and how it may be of help in this study. Then, literature on knowledge ecosystems will be shown, and it will be explained how a mission is related to a knowledge ecosystem. Lastly, literature on the credibility cycle will be shown, and expectations will be given on possible changes to this credibility cycle due to a mission-driven KES.

Directionality

The study of Schot & Steinmueller (2018) on innovation policy describes three distinct frames of innovation policy that developed over time. The first framing came about after the Second World War, focused solely on innovation for growth, and looked at market failures. Support for science and R&D were the main policy measures in this first frame. The second framing elaborated on this approach by looking at system failures as well, inspired by the literature on innovation systems. Policy became more focused at building linkages between elements of the system. Schot & Steinmueller (2018) argue that a third frame on innovation policy is needed, which can help shape policy for transformative change and the 'grand challenges'. It is argued that new policy measures on transformative change should complement current market failure and system failure policies.

This third frame proposes four new types of failures. These are directionality, policy coordination, demand articulation and reflexivity (Schot & Steinmueller, 2018). This thesis uses the concept of directionality to study the influence of mission-driven KESs on an individual researcher. Directionality failure refers to setting a direction to induce transformative change (Weber & Rohracher, 2012). This can be done by setting collective priorities and considering a diverse set of options for transformative change. Moreover, directionality failure describes how there is a lack of prioritising social choices in alternative development pathways (Schot & Steinmueller, 2018). Addressing directionality failure requires policymakers to set collective priorities and look beyond the narrow boundaries set by incumbents.

Missions and directionality are inherently related to each other. Schot and Steinmuller (2018b) propose that missions should be understood openly in contrast to other authors favouring a more top-down approach to setting up missions and giving direction via these missions. Open missions should therefore be constructed by addressing directionality. Meaning that a diverse set of options should be considered while setting up missions.

In this thesis, we analyse how a mission-driven KES may provide directionality to a particular sector and individual researcher. This may be in the form of setting collective priorities and goals. In this way, a

mission-driven KES can influence the direction and induce a certain pathway. However, a mission-driven KES is not something that inherently induces transformative change. For example, certain private actors may have too much power in setting the direction and mission of a KES. It is, therefore, important to consider the concept of directionality and look critically at the formulated mission of mission-driven KES.

Knowledge ecosystems (KES)

Literature on knowledge ecosystems (KES) may help explain how a group of heterogeneous actors can work together to create and share new knowledge (Järvi et al., 2018). Moreover, the concept of directionality and literature on transformative change help in explaining the role of a mission in a KES. In this way, the concept of a mission-driven KES can be formulated.

It is important to understand that the concept of a knowledge ecosystem is part of a literature body on ecosystems in general. The concept of an ecosystem comes from biology and was first used in the management sphere by Moore (2006). The concept in the management sphere bears a resemblance to the biology term in the sense that both are focused on the self-management of a system. In which there is interdependency and co-evolution between different kinds of actors. However, this analogy has been questioned by many scholars as most of the time, ecosystems are, for example, deliberately designed in contrast to natural ecosystems. Therefore, we must be careful with using the term as a metaphor. Accordingly, this thesis will use the concept of an ecosystem and a knowledge ecosystem more as a self-standing concept (Almpanopoulou, 2019).

The concept of an ecosystem in management and innovation literature has seen an increasing interest and, therefore, many different definitions. Therefore Thomas & Autio (2020) proposed the following definition of an ecosystem: *a community of hierarchically independent yet interdependent heterogeneous participants who collectively generate an ecosystem output*. Via this definition, the different types of ecosystems can be explained and delineated. These are business, innovation, entrepreneurial and knowledge ecosystems, which differ in their ecosystem output (Valkokari, 2015).

In this thesis, the focus is on knowledge ecosystems. Therefore, the definition (Thomas & Autio, 2020) can be used as follows: a community of hierarchically independent yet interdependent heterogeneous participants who collectively generate knowledge. However, the definition can be more precise and focus on important knowledge ecosystem dynamics. Valkokari (2015) and Järvi et al. (2018) can help with this definition. Valkokari (2015) elaborates on the output of a knowledge ecosystem and describes this outcome as: creation of new knowledge through joint research work, collaboration, or the development of a knowledge basis. So, the output of a knowledge ecosystem is new knowledge and comes about

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through joint research work and collaboration. Järvi et al. (2018) expand on the kind of participants and actors in knowledge ecosystems. Actors in knowledge ecosystems are universities, public research institutions and for-profit firms. Moreover, Järvi et al. (2018) elaborate that collaboration to create new knowledge happens in a pre-competitive setting. In this way, the following definition can be proposed: *a community of hierarchically independent yet interdependent heterogeneous actors, such as universities, public research institutions and for-profit firms, collectively generating new knowledge in a pre-competitive setting.*

Autio and Thomas (2021) propose four types of characteristics that distinct ecosystems from other types of collective constructs, such as networks and clusters. These characteristics can help in conceptualising a mission-driven knowledge ecosystem. These four main characteristics are participant heterogeneity, system-level outcome, nature of interdependencies, and coordination mechanisms.

Heterogeneous participants

A group of heterogeneous participants characterises ecosystems. For knowledge ecosystems, this is the case as well. This means that stakeholders in knowledge ecosystems come from different backgrounds and different kinds of organisations, ranging from private actors in different industries to academia in different disciplines (Järvi et al., 2018).

System-level outcome

In contrast to conventional organisational networks, ecosystems create one system-level output. In the case of knowledge ecosystems, this system output is new knowledge. Stated by Järvi et al. (2018) as: *"collaborative exploration of new knowledge as central activity and output"*. All in all, actors in a knowledge ecosystem interact to create new knowledge that could not be created alone (Autio & Thomas, 2021).

Interdependence

Ecosystem literature proposes interdependencies that are apparent in an ecosystem (Robertson, 2020). These are technological, economic and cognitive (Autio & Thomas, 2021). Technological interdependence mainly concerns the co-specialisation of heterogeneous actors around one knowledge base. This means that different actors bring other types of knowledge into this knowledge base, which brings interdependence between the different types of actors. Economic interdependence describes the value that each member of the ecosystem receives. In the case of a knowledge ecosystem, members are interdependent to share knowledge and create knowledge spillovers to increase the knowledge base of the ecosystem. Finally, cognitive interdependence describes how an ecosystem is socially constructed in

its beliefs, assumptions and values. Because of the heterogeneity of the members, it is essential to create this cognitive interdependency. Without it, they might not understand each other. Therefore, a collective identity is important for binding participants (Autio and Thomas, 2021).

Coordination

Ecosystems are characterised by coordination mechanisms which rely on role definitions, complementarity and alignment structures (Autio and Thomas, 2021). Instead of formal contracts between stakeholders, ecosystems are coordinated with informal measures. For instance, the KES's collective identity helps to give participants a shared identification and induces actors to confront challenges jointly (Autio and Thomas, 2021).

All in all, the definition used for a knowledge ecosystem in this study is as follows: a community of hierarchically independent yet interdependent heterogeneous actors, such as universities, public research institutions and for-profit firms, which collectively generate new knowledge in a pre-competitive setting. Furthermore, a knowledge ecosystem can be characterised by consisting of heterogeneous participants; aiming for a system-level outcome; inducing interdependencies; and by informal coordination.

Credibility Cycle

Literature on directionality and KESs have given a sense of how a group of heterogenous actors can cooperate for a societal mission. Literature on the credibility cycle may shed light on the process of scientific knowledge production and sharing in a mission-driven KES by looking at the individual researcher itself and its research process. Literature on the credibility cycle will be elaborated upon in this section, and expectations of the influence of a mission-driven KES on the credibility cycle of individual research will be given.

The credibility cycle shows researchers' motivations to conduct specific research and how researchers accumulate credibility over time (L. Hessels et al., 2019). Credibility can be seen as a form of capital or credit for a scientist to conduct research. In this way, credibility enables a researcher to do research and re-invest its acquired credibility into new research (L. K. Hessels & van Lente, 2011). This model can give new insights into the mobilisation of academic research for societal missions, as it shows the motivations of researchers and how a KES can help activate these motivations towards societal missions.

This process of accumulated credibility can be seen in Fig 1, in which conversions occur between money, staff and equipment, data, arguments, publications and recognition (Latour & Woolgar, 2013) (L. Hessels et al., 2019). Money in the form of funding is needed for researchers to pay for equipment and their staff.

Equipment and staff are needed to form new research data. The research data is used to formulate new arguments. New arguments are converted to academic publications. Whenever these publications are cited, they are converted into recognition for a researcher. Finally, this recognition is used to acquire new money and funding for staff and equipment. In this way, the credibility cycle is a repetitive process in which researchers earn a reward for each step and invest this in the following step, see figure 2 (L. K. Hessels & van Lente, 2011).



Figure 2, the credibility cycle (Latour & Woolgar, 2013)

This thesis uses the credibility cycle in a new kind of setting. A setting of a mission-driven knowledge ecosystem (KES), in which there might be more coordination and cooperation between different scientists and different research groups. A KES induces joint research work between different organisations (Valkokari, 2015). This might change the different kinds of credibility steps and induce different kinds of conversions between these credibility steps (Hessels et al., 2019). Hessels et al. (2009) already proposed several changes to the credibility cycle due to the changing 'contract' between science and society (e.g., earmarked funding and performance assessments). Moreover, the mission of the KES might induce changes to the credibility cycle of the researcher.

Recognition – money

Recognition is defined as a scientist's (in)formal reputation (L. K. Hessels & van Lente, 2011). Scientists or scientific communities can receive recognition from peers or scientists in other disciplines (L. Hessels et al., 2009). Money is defined by the funding for research, which is obtained by individual scientists or groups of scientists (L. K. Hessels & van Lente, 2011). The conversion from recognition to money is mainly determined by funding structures. In the Netherlands, scientists can, for example, acquire funding from different sources, such as the Nederlandse Organisatie voor Wetenschappelijk Onderzoek (NWO), European Union Framework Programmes (FPs), industry and NGOs. Moreover, scientists or groups of scientists are rated on official performance evaluations (L. K. Hessels & van Lente, 2011).

In the context of a mission-driven KES, this conversion of recognition to money may be shaped differently. For example, a KES has an organised funding structure; this may use other principles, criteria or research goals than a regular public research funder (Järvi et al., 2018). For example, private actors that provide funding may have other requirements. These requirements may be less based on academic competencies but more on competencies which are needed in the industry. Furthermore, performance evaluations may be based more on the researcher's contributions to societal challenges in a mission-driven KES. This means that a researcher may need to have shown a previous interest in the societal challenge.

Money – staff and equipment

Money represents funding for research activities. This can be in the form of earmarked funding for certain staff members or equipment in a laboratory (L. Hessels et al., 2009). Several mechanisms determine the conversion from money to staff and equipment. Selection procedures are one way to determine what kind of staff is hired for conducting research. Selection procedures mainly examine criteria such as publication and citation records (L. Hessels et al., 2009).

A KES is defined as establishing cooperation between different kinds of organisations and, consequently, new interactions between individuals (Järvi et al., 2018). This might influence the conversion from money to staff and equipment. New personnel might be recruited, which would not be connected without the KES, or other disciplines might get involved in the research. Physical assets such as lab facilities, equipment, samples, materials and test facilities may more easily be shared between researchers and organisations. More funding might also be available to researchers to buy equipment or materials due to the involvement of private actors.

Staff and equipment – data

Staff and equipment represent the physical and personal assets to do scientific work, and data represent findings from scientific work (L. K. Hessels & van Lente, 2011). The conversion from staff and equipment to data mainly happens in the form of scientific research in laboratories or other research locations (Hessels et al., 2009). The conversion mainly covers the choice of which data should be produced, which may be determined by a funding agency or other social pressures (L. Hessels et al., 2009).

As said before, other disciplines might interact due to the KES, as a KES is characterised to be a heterogeneous group of actors (Järvi et al., 2018). This interaction between different disciplines might deliver new findings, which would not have been found without the KES. This interaction might mean that different organisations produce their data in the same lab. Moreover, a new conversion might take place between data and recognition. As data is more easily shared in a KES and might give researchers already

some recognition inside the mission-driven KES. Finally, the choice to produce data may be influenced by the mission of the KES and the organisations that shaped this mission. It might be interesting to see how significant this influence is on private actors and if the research work is still robust.

Data – arguments

Data represents findings from scientific work and arguments are defined as contributions to scientific debates by interpreting findings (L. K. Hessels & van Lente, 2011). This conversion mainly depends on the norms in a scientific field if and when specific data possess the needed characteristics before they can support arguments (L. Hessels et al., 2009). Other influences can come from outside parties, which may influence the conversion from data to arguments (L. K. Hessels & van Lente, 2011).

A KES is defined as setting goals for the ecosystem (Järvi et al., 2018). This goal might interact with the conversion of data to arguments. For example, a researcher might interpret the findings differently as the context of the research has changed due to the goal of the KES or the corresponding goal of the research, which got funding from a partner of the KES. There might also be more interactions with organisations in the mission-driven KES when interpreting findings. This might mean that private actors or PROs provide feedback to the researcher and, in this way, influence how the researcher interprets the data.

Arguments – articles

Arguments are contributions to scientific debates by interpreting certain findings, and articles are defined by publications or other deliverables (L. K. Hessels & van Lente, 2011). This conversion mainly describes how and in what way a researcher or a group of researchers decides to convert their scientific work into output (L. Hessels et al., 2009). This can be in the form of publishing in scientific journals, publishing patents or delivering a scientific report (L. K. Hessels & van Lente, 2011).

A KES is not only focused on collaborating for the output of scientific articles. Other deliverables in a KES could become more important. For example, researchers might give presentations at firms and present how their research is of value for a private firm or PRO, which is usually not done by academic researchers. These presentations might also be given at certain events to a broader public (Järvi et al., 2018). Moreover, applications for private actors and PROs might emerge from the research instead of just an academic article. This might mean that researchers become concerned with publishing certain patents.

Articles – recognition

Articles are defined by publications or other deliverables, and recognition is defined as the (in)formal reputation of a scientist, which is mostly based on scores in formal quality assessments (e.g. research evaluations and performance assessments) (L. K. Hessels & van Lente, 2011). The conversion from articles

to recognition is mainly determined by academic publication and corresponding criteria such as the number of publications and citations (L. Hessels et al., 2009).

In the context of a KES, a scientist's reputation in the ecosystem itself may become more important. For example, it may be important in what way a scientist's research has helped with the formulated goal of the KES and its relations with actors in the mission-driven KES. Vice versa, the reputation of the KES in the outside world also influences the recognition of a researcher. This can be positive when a mission-driven KES has good publicity, but it can also be a negative influence. Furthermore, a scientist's reputation may improve due to the societal relevance of the mission-driven KES. This may be in the academic world but may also be of importance outside the academic world. Finally, scientists' reputation may increase not only in the academic world but also in industry or other sectors in which the KES operates.

Synthesis

In this study, it is researched how certain characteristics of a mission-driven KES may influence certain steps of the credibility cycle of a researcher. Literature on KESs and mission-driven KESs is underdeveloped, and more conceptualisation of both concepts is needed. This study tries to explore this strand of research by giving it empirical evidence. The research of Järvi et al. (2018) and Thomas and Autio (2020) are used as the main building blocks for this study on KESs. The literature on KESs is receiving critique in the academic world as it is being seen as a vague concept and not that different from a network or other cooperating mechanisms. We acknowledge the fact that literature on this subject is still underdeveloped. But as it is a concept that is being used in the policy sphere, it may be beneficial to give the concept more attention in the academic world (Rijksoverheid, 2020). Directionality, missions and transformative change are also upcoming in the innovation policy word, while still being underdeveloped in its conceptualisation and application. The credibility cycle is a theory that has existed for a longer time and is therefore more conceptualised. This makes it a good framework to study knowledge production and sharing in a mission-driven KES and how the researcher itself works in such a system. All in all, theories on KESs, directionality and the credibility cycle are critically studied and examined on its relations in the real life case of CATO.

Methods

In this section, the methods of the research will be elaborated upon. First, the research design of the study will be sketched. Second, the case will be explained. Third, the data collection of the research will be explained. Fourth, the data analysis of the research will be elaborated upon. Fifth, an operationalisation of some theoretical concepts is given. Lastly, the reliability and validity of the study will be explained.

Research design

The study has the following research design. Firstly, theory on KESs, the credibility cycle and directionality were studied. Essential concepts were gathered and combined to form a framework to study the influence of a mission-driven KES on the credibility cycle of a researcher. Then this knowledge was used to conduct a case study on the mission-driven KES of CATO in the Netherlands in retrospect. The case was studied to test the framework and to get new insights into the effect of a mission-driven KES on an academic researcher. The case-study approach will help get in-depth knowledge of dynamics in a mission-driven KES of CATO (Bowen, 2009). Then a more in-depth analysis was done by carrying out semi-structured interviews.

This research is qualitative, as complex social phenomena were studied. There is a need to understand the relationship between academic researchers and the directionality of a mission-driven KES. Moreover, the research is deductive. The current theory on a mission-driven KES and the credibility cycle are tested and given new empirical evidence. Such a research design will be beneficial as interpretations of people who experienced such mission-driven KESs might give new insights.

Case

CATO is a Dutch Carbon Capture and Storage (CCS) research programme. It was established in 2004 to build a strong knowledge network for CCS in the Netherlands, as CCS may be an important factor in reducing the emission of greenhouse gases by 'decarbonising' fossil fuels (Visser et al., 2009). The CATO programme has experienced different phases and is currently phased out in different programmes. The programme started with CATO-1, which was active from 2004-2009. CATO-1 was followed up by CATO-2, which was active from 2009-2014 (de Vos, 2014). From 2015 onwards, the CATO programme was taken in by TKI Gas (Top consortia for Knowledge and Innovation) and other national and international CCS collaborations (de Vos, 2014). The CATO programme office is still active and coordinates some CCS activities in the Netherlands. This research will focus on the first two programmes, CATO-1 and CATO-2, with the timespan of 2004-2014. In this timeframe, the CATO programme was the most active and academic research played an important role in these two programmes (Van Egmond et al., 2012[4]).

CATO-1 was active from 2004-2008; in 2009, some PhD work was still being finished. CATO-1 consisted of 17 partners, ranging from companies (e.g. Shell), research institutions (e.g. TNO), universities (e.g. Utrecht University) and environmental organisations (e.g. Greenpeace) (Visser et al., 2009). The diverse stakeholders resulted in a broad scope of research activities and research disciplines in the programme, such as chemistry, geology and social sciences. CATO-1 was mostly focused on fundamental research and had a budget of around 25 million euros. This was subsidised for 50% by the Dutch government through the BSIK funds (Van Egmond et al., 2012).

CATO-2 was active from 2009-2014. CATO-2 saw an increase in partners, from 17 in CATO-1 to 40 in CATO-2, which comes down to 400 persons (de Vos, 2014). While the diverse nature of stakeholders remained intact, a notable increase could be seen in the number of partners in the power sector (Van Egmond et al., 2012). Furthermore, the budget of CATO increased to 60 million euros. The programme was still subsidised for 50% by the Dutch government and 50% by private partners (Van Egmond et al., 2012). The fundamental nature of the programme changed to a mix of fundamental and applied research. There was a need for more applied research in the form of demonstration projects. The budget was spent accordingly, with around 25% on fundamental activities (Van Egmond et al., 2012).

CATO consisted of several sub-programmes or themes on which research was focussed. These were: carbon capture (SP1), transport and chain analysis (SP2), storage (SP3), regulation (SP4), public perception (SP5) and communication and coordination (SP0) (de Vos, 2014). In this thesis, the focus will be on SP1, carbon capture, and SP3, carbon storage. These two programmes were focussed on because of the fundamental nature of the research in these two programmes. We were interested how a fundamental researcher interacted with the societal mission of CATO.

SP1 is mostly focused on chemistry, related to capturing CO2 from the air. Before CATO was established in 2004, CO2 capture required 15-30% additional primary energy, regarded as the 'energy penalty' (Meerman et al., 2008). One of the goals of this subprogramme was to reduce this energy penalty, which required a new fundamental understanding of capture techniques. SP3 is mainly focused on increasing the knowledge of injection and storage mechanisms, the corresponding safety issues and monitoring this process. Multiple science disciplines worked together to answer the questions surrounding the storage of CO2, such as geology, geochemistry, petrophysics, geophysics, geomechanical engineering, mathematics and reservoir engineering (de Vos, 2014). PhD research was an essential part of the research in CATO and the two sub-programmes SP1 and SP3 (de Vos, 2014). Furthermore, the document analysis and an exploratory meeting with the director of CATO showed that the group of PhD researchers was very active in its research but also in being a social group. Lastly, the document analysis showed that human capital was created with the PhD researchers in CATO. Therefore, this study focussed on PhD researchers in these two sub-programmes.

The case of CATO suits this study as a heterogenous group of actors worked together to increase the knowledge base around CCS, with academic research on chemistry and geology and public perception of the technology. Furthermore, the group of PhD researchers were a social group, showing some interesting dynamics on cognitive interdependence of a KES. Lastly, the technology of CCS has public controversy surrounding it. Most projects in the Netherlands for CCS did not yet succeed. The case of CATO does not seem to meet the characteristics of a societal mission as the technology of the mission-driven KES has seen some public controversy. However, this might show interesting dynamics for the mission and directionality of such a KES and what we can learn of a mission-driven KES is formed around a technology which is questioned by society. All in all, CATO looked to be an interesting case for a mission-driven KES.

Data collection

Two types of qualitative data were collected, these are documents and interviews. Triangulation was used to combine multiple data sets and control certain findings from documents through interviews and vice versa. First, data was collected on the structure of the KES as it had to become clear which actors are participating in the ecosystem and how they are related. Then, published documents by the KES itself, participants and outside researchers looking in were used to collect qualitative input on dynamics among individual researchers and organisations participating in the CCS ecosystem. For example, a study has been carried out on the knowledge network of CCS in the Netherlands (Van Egmond et al., 2012). Data from scientific studies and other reports have been used to get further insight into the research question and to get new input for the interviews.

PhD research was the main object of this research. As said before, the PhD group showed interesting dynamics in being a social group of people with different backgrounds. Furthermore, CATO connected these PhD students to industrial partners. All in all, some interesting insights were seen in the document analysis, and therefore, PhD students were interviewed about their role in CATO and how CATO influenced their PhD research. Supervisors of PhD students, coordinators and the director of the CATO program were also interviewed. In this way, this research gives a good overview of the PhD work from the PhD students themselves as from people who oversaw their work. In the interviews, data was gathered on the credibility

cycle of PhD researchers and on characteristics of a mission-driven KES that influenced the credibility cycle of the PhD researcher.

Documents on the KES were collected on the website of CATO; through search work on google scholar, web of Science and NexisUni for scientific work, and on Google for grey literature on the subject. The CATO programme website was used to find respondents for the interviews. Around 30 PhD students worked for the two sub-programmes SP-1 and SP-3, of which nine were interviewed. Three supervisors were interviewed. One coordinator was interviewed, and the director of CATO was interviewed. So, in total, 14 interviews were conducted. Interviews were held with participants through semi-structured interviews. In this way, interviewees were allowed to deviate from the interview questions. Therefore, a more in-depth understanding of the phenomena was gained, while at the same time, interviews are still comparable (Bryman, 2016).

The interview guide can be found in appendix A. The interview guide focused on getting as many insights as possible into the PhD work of the researchers and how CATO influenced it. This was done by dividing the questions into a couple of subjects. First, some questions were asked on their view of CATO and the goal or mission of CATO. Then questions were asked about the role of the PhD researcher in CATO. Then questions on the research process were asked. This was not done by going through the credibility cycle step by step. Instead, the research process was divided into different parts, such as admission into CATO, starting up the research, carrying out the research process. Lastly, some questions were asked about public perception and public controversy around CCS to get insights on whether this played a role in their PhD work. To address the difference between the PhD researchers themselves and people from the outside looking in, we created two different interview guides. Interviews were transcribed to make a sufficient analysis of the interviews possible. Lastly, an informed consent form and information sheet about the interview were provided to interviewees (see appendix C).

Data analysis

Firstly, the document analysis was carried out. The document analysis was mainly done to get an overview of CATO as a mission-driven KES. The different characteristics of a mission-driven KES were researched via these documents. Moreover, the documents were used to get some first insights into the PhD research and how the mission-driven KES of CATO might have influenced this.

Secondly, the interviews were analysed. This was done by coding the interview transcripts in AtlasTi. The coding of the transcripts was done deductively. First, the different characteristics of a mission-driven KES

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were used to code the interview transcripts. Then the different steps of the credibility cycle were used to code the interviews. In this way, how and which characteristics influenced certain steps of the credibility cycle could be examined. Some interview findings were difficult to place in one of the two theoretical concepts and were therefore seen as alternative explanations. These were later seen as contributions and alternations to the current theory on a mission-driven KES and the credibility cycle. Lastly, the interview transcripts were coded on exogeneous factors on the mission-driven KES. This was mainly coded as such when the interviewe talked about public controversy and how this influenced the mission-driven KES of CATO. All in all, the interview transcripts were coded on all these different aspects. In this way we could see how codes on the mission-driven KES overlapped with codes on the credibility cycle. Showing a relation between a characteristic of a mission-driven KES and a conversion step of the credibility cycle.

Operationalisation

In order to carry out a coherent analysis of the interviews and documents, an operationalisation of the theoretical concepts was needed. This was mainly done to get a coding scheme for analysing the data of this study (Appendix B). The credibility cycle was coded on the different elements of the credibility cycle. If an interviewee mentioned something about data or recognition, it was coded as such.

The concept of a mission-driven KES needed operationalisation. A mission-driven KES has several characteristics that are interesting to analyse for this study. These are the four following characteristics: heterogeneous actors, relations, knowledge and goals. These are derived from the four characteristics of Thomas and Autio (2020) and Järvi et al. (2018) in the theory section. Participant heterogeneity is turned into actors. The system-level outcome of knowledge is turned into different knowledge steps. The nature of interdependencies and coordination mechanisms are turned into relations and goals. Lastly, the study of Järvi et al. (2018) and the concept of directionality was used for conceptualizing goals of a mission-driven KES. Table 1 provides an overview of the characteristics of a mission-driven KES. The interviews transcripts were coded on these characteristics of a mission-driven KES.

Heterogeneous actors

A mission-driven KES is characterised by a heterogeneous group of actors (Thomas & Autio, 2020). Actors include academia, public research organisations, private and societal actors. Furthermore, the actor group themselves consists of different kinds of actors. Academia can, for instance, contain several different academic disciplines. A KES consists of a heterogeneous group of actors, which is an important characteristic of a mission-driven KES and explains essential dynamics in a KES (Järvi et al., 2018). It, for example, facilitates the creation of new knowledge through joint-research work.

Relations

A couple of relation types can characterise a mission-driven KES. Firstly, a KES is a social network (Autio and Thomas, 2021). This characterisation facilitates the sharing of knowledge between different actors. Furthermore, a mission-driven KES can induce new relations or reinforce relations which are already present. Lastly, relations in a mission-driven KES can be conscious or subconscious. In the sense that actors seek contact on purpose or that a new relation mainly happened accidentally.

Knowledge

A primary characteristic of a mission-driven KES is knowledge, which is the primary system-level outcome of a KES (Valkokari, 2015)(Thomas & Autio, 2020). Several types of knowledge can be distinguished. This is delineated by the different steps in the process of knowledge production and sharing in a KES. The first step in this process is agenda-setting. The heterogeneous group of actors all influence the agenda of the KES and try to incorporate their individual goals as much as possible (Järvi et al., 2018). The second step is the creation of knowledge. Actors, such as academia, start to create knowledge that aligns with the agenda and the goal of the mission-driven KES (Järvi et al., 2018). The third step is the sharing of knowledge. All actors share their knowledge and might come up with new knowledge. The fourth step is the further development of knowledge. The knowledge that is created and shared within the KES is further developed by private actors or public research organisations. The last step is the dissemination of knowledge in the mission-driven KES. The new knowledge of the KES is shared with actors outside the mission-driven KES at academic conferences, for example.

Goals

The concept of directionality is of importance during the process of goal-setting in a mission-driven KES. A mission-driven KES consists of a heterogeneous group of actors which makes that these actors have different kinds of goals (Järvi et al., 2018) (Cobben et al., 2022). The goals of the different levels and actors in the KES thus influence the direction of the KES. The main obstacle here is the prioritisation of specific goals and the drafting of the mission through setting collective priorities (Weber & Rohracher, 2012).

People in a mission-driven KES have individual goals (Järvi et al., 2018). This individual goal can, for instance, be to gather more recognition or money by operating in a mission-driven KES. Another goal is on the organisational level. Private actors may have other goals for operating in the mission-driven KES than academia. The sense that private actors mainly seek an economic benefit, while academia might prioritise good research (Autio & Thomas, 2021). The third type of goal is on the ecosystem level. A mission-driven KES is an organised system consisting of an administration or management with its own

goals with the KES. These goals might be related to shared goals of the whole ecosystem. Lastly, there are societal goals in play in a mission-driven KES. A societal challenge is vital in a mission-driven KES, and therefore, a societal goal is represented by the mission-driven KES.

Characteristics mission-driven KES	
Actors	- Academia (different disciplines)
	- Public Research Organisations
	- Private actors
	- Civil society
Relations	- Social network
	- New/existing relations
	- Conscious/subconscious relations
Knowledge	- Agenda setting
	- Creation
	- Sharing
	- Development
	- Dissemination
Goals	- Individual goals
	- Organisational goals
	- Ecosystem goals
	- Societal goals

Table 1: Characteristics of a mission-driven KES

Reliability and validity

Four indicators control the quality of the study. These are credibility, dependability, confirmability and transferability (Lincoln & Guba, 1985). Credibility relates to the confidence that the findings of the study are valid. The research findings must represent plausible information from documents and participants in interviews. The study's credibility is assured by conducting interviews with different kinds of respondents

(PhD researchers, supervisors, coordinators and a director) and by checking transcripts and results with interview respondents after the first concept version. Dependability relates to the stability and trackability of changes in data over time. The dependability of the study is assured by the triangulation of methods using interviews and documents. Confirmability refers to the objectivity of the study. The objectivity is assured by using multiple data collection methods and a semi-structured interview. Finally, transferability concerns the generalisability of the research. The generalisability is assured by showing the boundaries and characteristics of CATO, allowing comparison to be made.

Results

In this section, the results of the research are shown. First, the case of CATO is analysed through the characteristics of a mission-driven KES. Then, the influence of the mission-driven KES of CATO on the credibility cycle of the PhD researcher is shown. Finally, the role of directionality is elaborated.

Characteristics mission-driven KES

Heterogeneous actors

As mentioned, CATO consisted of a set of heterogeneous actors. Universities, such as TU Delft, Utrecht University and TU Eindhoven, operated in the KES (de Vos, 2014). Moreover, several disciplines were involved, ranging from chemistry to social sciences. The universities were represented by professors, postdocs and PhD researchers (Van Egmond et al., 2012). Private actors were also active in the mission-driven KES of CATO. These were mainly firms active in the energy sector, such as E-On, Shell, RWE, Vattenfall and Gasunie (de Vos, 2014). Public Research Organisations (PRO) also played a significant role in the missiondriven KES, mainly TNO and ECN. Lastly, NGOs and the public played a role in the mission-driven KES of CATO. NGOs such as Natuur en Mileu and Greenpeace had some influence on the programme (Visser et al., 2009). Finally, the public was involved in research on, for example, public perception.

Relations

CATO had several mechanisms to induce and create certain relations between PhD researchers themselves, and PhD researchers and other actors in the KES. The first important mechanism was the CATO days. The CATO days took place two times a year, and they were special conferences on which all actors gathered (Van Egmond et al., 2012). On these CATO days, there were special meetings of certain sub-programmes and general meetings in which presentations were given. The sub-programme meetings focused more on specific subjects, and PhD students could get feedback from academics in their field or private actors (de Vos, 2014). The general meetings had a more diverse audience, consisting of PhD researchers, academics, private actors, PROs and NGOs (Interviewees). At these general meetings, PhD researchers could present their work to people outside their field, learning how to present their results to people without in-depth knowledge of their work (Interviewee 4,5,12). More importantly, they would watch presentations of researchers outside their discipline (Interviewee 4). Ultimately, the CATO days induced new relations between PhD researchers and other actors in the mission-driven KES (de Vos, 2014).

The second important mechanism for new relations was the CATO field trips. CATO organised field trips to interesting sights, such as Barendrecht, Groningen, England and the Eiffel (Interviewees). These field trips were organised by the coordinators from CATO and were meant for PhD researchers to get more practical knowledge and to create a community with all researchers (de Vos, 2014).

All in all, CATO brought people from diverse backgrounds to each other. Mostly, these were all new relations between PhD researchers and PhD researchers and other stakeholders. Furthermore, these activities created a social network where people knew each other well (de Vos, 2014).

Knowledge

CATO had an influence on several parts at the knowledge level. Agenda setting was important at the start of CATO and mostly happened between the programme office of CATO and actors such as Shell and TNO (Interviewee 6,12,13). They decided what kind of research would be essential and made certain subprogrammes to which funding was allocated (Interviewee 12,13). Knowledge creation mainly happened through research of academia (e.g. PhD research), TNO and some research at private actors, such as Shell (Interviewee 13). Knowledge sharing was a part of the mission-driven KES and mainly happened at subprogramme meetings, CATO days and CATO excursions. Knowledge sharing happened between experts in the same discipline, but more importantly, some trans-disciplinary sharing of knowledge was facilitated at the CATO days and CATO excursions (de Vos, 2014). Further knowledge development mainly happened at the private actors and PROs but was mainly done after CATO (Van Egmond et al., 2012). Finally, the dissemination of knowledge mainly happened at conferences for academia.(Van Egmond et al., 2012)

Goals

As said, a heterogeneous group of actors participated in the CATO programme. This also meant that participants had different goals. Participants had personal goals by participating in CATO. Personal goals were, for example, getting more recognition in the academic world. Organisational goals differed between the type of actors. Private actors were interested in developing a technology that could help them continue their current work while reducing their emissions. Academia were more interested in producing knowledge and helping the field of CCS with new fundamental and applied knowledge (Van Egmond et al., 2012). There were also ecosystem goals linked to CATO. The CATO-1 goal was "to find out whether the promises of capture and storage of the greenhouse gas carbon dioxide will hold for the Netherlands" (Visser et al., 2009). The goal of CATO-2 changed; according to Van Egmond (2012), the goal was as follows: the CATO-2 programme was established with a mission to facilitate the integrated development of CCS demo sites in the Netherlands, to work on innovation for new CCS generations, and to build a

strong knowledge network around CCS. CATO-2 aims to integrate the full CCS chain, including – in addition to capture, transport and storage – public perception and legislation. There were also societal goals linked to CATO, mainly based on the energy transition and how CCS can help with this transition (Van Egmond et al., 2012). Moreover, there was research into public perception of CCS, which shows some societal connection.

Credibility cycle

This section shows how the mission-driven KES of CATO influences PhD research and the credibility cycle of a PhD researcher. All the different steps of the credibility cycle will be elaborated upon.

Recognition -> Money

The recognition of a PhD researcher differs somewhat from a typical regular researcher, as PhD researchers are in the initial stage of their academic career and have yet to obtain significant recognition in the academic community. Instead, recognition is mainly obtained through connections with certain professors with whom they have worked during their master's degree. Interviewees mentioned that they asked their supervisor if there were any interesting PhD positions, or their supervisor asked them if they were interested in a PhD position. Their promotor or supervisor made this decision on their prior experience working with the PhD student or on the knowledge that they were pursuing a PhD position. Upon obtaining a PhD position, researchers receive funding to conduct their research, representing a critical intermediate step between recognition and money. The following quote highlights this point:

"Het project was al besproken zeg maar met tussen de sponsoren en dus de professor en dan moest de professor nog iemand vinden die dat project zou kunnen uitvoeren. En ja dan was het aan de professor om te beoordelen volgens mij van wie daarvoor een goeie kandidaat was. Dus ja, en eigenlijk dan heb je de enige eis die d'r echt formeel is. Dus van ja dat je dus een diploma moet hebben, een master of science. En ja de professor moet het vertrouwen erin hebben dat je dat project kan doen." (Interviewee 2)

CATO does not directly influence this conversion from recognition to a PhD position. CATO lets promotors or supervisors decide if a particular student is fit for a PhD position. However, CATO indirectly affects this conversion, primarily due to the societal goal of CATO and the involvement of a heterogeneous group of actors. Interviewees reported being attracted to the PhD position because of the societal goal of addressing climate change through CCS and CATO. Other interviewees mentioned they were motivated to pursue CATO because they wanted their PhD research to have an impact. The fact that CATO was such an extensive collaboration of actors meant something to them. The following quote illustrates this point:

"Want ik was vrij snel enthousiast omdat, ik vind het wel belangrijk dat datgene wat je onderzoekt, zoals ik al eerder zei, niet voor de leuk op de plank, maar dat het nut dient dat de maatschappij er wat aan heeft." (Interviewee 3)

The mission-driven KES of CATO directly influences the conversion from the PhD position to money. The CATO program office has established several sub-programs in collaboration with a group of stakeholder, with a certain amount of funding allocated to each. These sub-programs are designed to address specific research problems or topics, and as such, CATO determines which research areas and PhD subjects receive funding. Consequently, the diverse goals of CATO dictate these preferences. Therefore, it falls upon CATO's program office to integrate organisational, societal, ecosystem, and personal goals into one cohesive program, shaping the types of developed PhD subjects. The following quote highlights this point:

"Ja, dan kom je met een soort outline ook inhoudelijk van het programma wat je zou willen doen. En dan ga je praten met alle partijen en dan heeft dus TNO wensen op gebied van afvang en opslag en allerlei andere partijen. Als Shell mee moet betalen ja dan wil ze natuurlijk ook dat een onderzoek gebeurt wat voor hen interessant is. Datzelfde geld voor TNO en t zelfde geldt voor Gasunie, dus allerlei partijen maar ook een milieubeweging die dan met bepaalde verlangens kwam van ja de zorgen die ze hebben. Dus dat je ook daar aandacht aan zou schenken." (Interviewee 12)

Overall, the mission-driven KES of CATO shaped and influenced the conversion of recognition to money for a PhD researcher. Firstly, the conversion was shaped differently since a PhD student does not acquire funding in a normal academic way. The student must acquire a PhD position and, in turn, gets funding for their research. The societal character of a mission-driven KES influenced the decision to do PhD research for CATO, and the recognition they received from their professor determined if they would be applicable for the position. Secondly, the conversion was influenced by the funding structure of CATO, which decided what kind of research would get funding.

Money -> Staff and Equipment

The mission-driven KES of CATO influences the conversion from money to staff and equipment through two distinct mechanisms. Firstly, CATO provides considerable funding for carrying out the research. The KES provides funding to buy new equipment, materials and samples for PhD. Interviewees mentioned they had more funding available to buy certain equipment, in contrast with normal (PhD) research. The following quote shows this point: "Ik had daardoor wel beschikking over meer fondsen dan andere onderzoekers. Daardoor kon ik wat apparatuur kopen. Die mij geholpen hebben, dus indirect maar niet. Ik heb wel één keer via Shell een gas chromatograaf gekregen. Die heb ik zelf niet gebruikt, maar die is wel bij de TU delft terechtgekomen en ik denk wel dat de TU delft die gehad heeft omdat wij allemaal in het CATO programma zaten." (Interviewee 7)

Another approach PhD students used to acquire equipment or materials was the social network of CATO. There was a considerable amount of sharing of equipment and materials between PROs, private actors and the PhD researchers themselves. The social network of CATO enabled PhD students to get new relations with these actors to acquire the needed equipment. Interviewees mentioned that it was easy to get in contact with other people and that they would quickly get certain materials without too much trouble. The following quote underlines this point:

"This type of institutional interaction on the level of people where they don't say: Oh, I need to ask my manager, I need to ask the safety instructor, I need to ask the HR. How do we do this? To go through all the administrative hoops. No, I know you need it. I know you work with the same departments." (Interviewee 11)

All in all, CATO influenced the conversion from money to staff and equipment in two main ways. First, PhD researchers had access to more funding for acquiring equipment, and they could easily contact other actors to borrow or use their equipment or materials. The usage of staff was not significantly influenced by CATO, mainly because the PhD researcher carried out the PhD work alone.

Staff and equipment -> Data

The mission-driven KES of CATO influences the conversion from staff and equipment to data in multiple ways. The first primary influence is the research design (agenda-setting), which is influenced by the demands and goals of actors in the KES. The type of demands and goals for the research determines what kind of data needs to be produced and is therefore important for this conversion. However, this influence is only significant in the setting of the goals of the research. Afterwards, PhD researchers get a relatively amount of freedom to make their own decision in setting up the research design. The following quote illustrates this point:

"Want toen ik begon was er een A-viertje met een ruwe lijn. Ik weet wel dat we uiteindelijk dat wel echt ontzettend verfijnd en hebben en ingevuld hebben. Maar er was wel een globaal plaatje van nou ja, het moet ongeveer hier naartoe." (Interviewee 4) Another influence of CATO on this conversion was the new relation between different heterogeneous actors. Due to CATO, academia from different universities encountered each other and could perform experiments together. Other interviewees mentioned that they did lab work in collaboration with private actors and PROs. In this way, multiple organisations created certain data and knowledge together. Moreover, interviewees mentioned that they could better match their work due to these newly formed relations. The following quote underlines this point:

"Ja we deden daardoor experimenten onderling. Utrecht hadden microscoop en wij hadden de CTscanners. Utrecht had wat beter micro werk, wij waren weer beter in beeldsystemen. Maar ja op die manier had je wel kruisbestuiving." (Interviewee 6)

All in all, the conversion from staff and equipment to data was influenced by the mission-driven KES. In addition, it was influenced by the different goals of the organisations inside CATO that shaped the research subject and, in a way, what kind of data was produced. Furthermore, CATO enabled heterogeneous actors to work together with lab work or experiments, making cross-fertilisation of knowledge happen.

Data -> Arguments

CATO influenced the conversion of data to argument via two mechanisms. Firstly, PhD researchers had sub-programme meetings with people involved in the same sub-programme or a research subject. At these meetings, different kinds of people and organisations were present, ranging from academia, researchers at PROs and representatives of private actors. In this way, PhD researchers would get helpful theoretical feedback from other researchers and more practical feedback from private actors or PROs. Multiple interviewees mentioned how these meetings helped them closely align their research to practical needs. The following quote shows this point:

"Want je had dus ook momenten waarop je aan de consortium partners moest uitleggen wat je had uitgevoerd. En de feedback die je dan krijgt is ook wel handig omdat je ja dat je daarmee de inzichten krijgt van mensen die bijvoorbeeld meer ervaring hebben met het veld. Nou dat was prettig. Dat je dus verschillende invalshoeken in dat consortium had, waardoor je een bredere kijk op het probleem waar je mee bezig was kreeg"......"Dat je die überhaupt gesteld krijgt is heel prettig, want t wat fijn is, is dat er mensen zijn die. Datgene wat je onderzoekt, die willen het toepassen ergens. En daarmee heb je meteen een serie mensen die geïnteresseerd is in wat je doet. En dat is heel prettig, omdat je dan een soort wisselwerking kan krijgen tussen je gebruiker en je wil natuurlijk niet een onderzoek doen en dat er dan een boekje komt dat mooi op de plank ligt." (Interviewee 3) Another mechanism of CATO that influenced this conversion was the CATO days and excursions on which different disciplines and PhD researchers would come together. PhD researchers could present their work to a broader audience and watch other PhD researchers present other kinds of PhD work. This enabled some interplay and cross-fertilisation between PhD students of different disciplines. They could improve their own work by presenting and receiving feedback while at the same time improving the work of other PhD students. The following quote illustrates this point:

"En dan was er nog één keer per jaar een Cato dag die georganiseerd werd met alle werkpakketten bij elkaar. Er zijn volgens mij drie Cato excursies geweest met alle promovendi van alle Cato werkpakketten bij elkaar. Dus daar waren dan alleen de promovendi bij betrokken en dat vond ik een van de sterke punten van CATO is dat ze echt probeerden te zorgen voor kruisbestuiving tussen de verschillende disciplines. En dat heb ik in weinig consortia meegemaakt tot nu toe." (Interviewee 4)

All in all, CATO significantly influenced the conversion of data to arguments. Partner organisations influenced the PhD work by indicating practical problems or needs. However, researchers stayed autonomous in their work and could decide how to convert data into arguments. Moreover, PhD researchers of different disciplines influenced each other because they would contact each other on CATO days and CATO excursions.

Arguments -> Articles

The mission-driven KES of CATO influenced the conversion from arguments to articles in multiple ways. The first type of influence was on the publication of the PhD work. However, this conversion was still closely aligned with the credibility cycle in a regular academic setting. PhD researchers published their PhD work in journals via articles. This mainly was work they did with their supervisors rather than with people or organisations inside CATO. Therefore, there was no significant influence of CATO. The following quote shows this:

"Ja dat besloot. Het merendeel is eigenlijk vanuit professoren en assistent professor ja die zijn bekend met alle journals die weten van oh ja, dit onderwerp sluit beter aan bij die journal en dat onderwerp meer bij die en bij die journal hebben we al iets ingestuurd, dus laten we nu die andere eens pakken en zo hebben dat een beetje verdeeld over de journals." (Interviewee 2)

The second influence of CATO on this conversion was the other type of outcomes that came out of the PhD research. Not only were articles published, but also presentations were given to private actors or

other partner organisations. In this way, the PhD research could have practical outcomes. The following quote illustrates this point:

"All of that was experience in TNO. And by the end, I had that measurement device that had 6 different types of measurement. I also got the opportunity to test it on a demonstration site in Karlsruhe. Two or three years ago, I was at TNO, and they still use it." (Interviewee 11)

Moreover, the research of PhDs could also lead to the outcome that an application would not work. This led to some research that showed that techniques would not work, for example. Multiple interviewees mentioned that their research led to the conclusion that no future research was needed, as the technique was not feasible. The following quote underlines this:

"Maar over het algemeen denk ik dat dat toch wel afgelopen was naar mijn bezoek. Dus er heeft een deel van de info, er waren ook andere onderzoeken, maar een deel van de info was dat er behoorlijke roadblocks zaten om dat in de praktijk uit te voeren. En ik denk dat mijn onderzoek wel heeft bijgedragen in de beslissing van die roadblocks zijn zo groot. Op dat paard gaan we niet wedden. Dat denk ik.". (Interviewee 7)

All in all, the research of the PhD students did not only let to academic articles. The research also led to other outcomes, such as presentations for industry partners and application-oriented outcomes. This shows that the outcomes of a PhD researcher in a mission-driven KES widen to outcomes for partner organisations, such as private actors or PROs.

Articles -> Recognition

The mission-driven KES of CATO had some influence on the conversion from articles to recognition. PhD researchers received academic recognition for their PhD work. They could obtain this academic recognition by going to academic conferences on CCS in the Netherlands or abroad. The following quote shows this:

"Ja, ik merk wel nu eigenlijk meer dus de afgelopen paar jaar dat die interesse d'r is en dat ik ook gevraagd word om mijn ervaring met CO2 cement interacties te delen. Onder andere door een Amerikaans forum ben ik gevraagd om uit te leggen wat ik daarvan denk." (Interviewee 3)

It was also mentioned that CATO had a positive image abroad and was seen as one of the leading scientific communities on CCS (Interviewee 12). Moreover, people saw CATO as a community where they could

learn (Interviewee 12). Therefore, it helped PhD students to be a part of this community in their contacts with academics outside the mission-driven KES of CATO.

Overall, CATO influenced the conversion of articles to recognition by giving researchers a good image in the outside world. However, most of the conversion stayed in the academic sphere and was not influenced by CATO.

Alterations to the credibility cycle

Certain results and influences of the mission-driven KES of CATO on the research work of PhD students cannot be placed and explained by the current credibility cycle. Therefore, we propose alterations or new steps to the credibility cycle. The first significant influence of CATO on a PhD researcher that cannot be placed in the current credibility cycle is broader knowledge. Due to the contact with other disciplines, firms and other organisations inside CATO, PhD researchers got broader knowledge on CCS. This broader knowledge was not limited to technical knowledge in other disciplines but also knowledge of social science, for example. Inside CATO, some research was done on public perception, for instance. The PhD researchers realised that their fundamental study was only a small part of the puzzle by getting in contact with researchers doing another kind of studies on the subject. Multiple interviewees expressed that this mechanism helped them in their PhD research and, more importantly, later in their careers. It helped them in seeing the bigger picture. The following quotes illustrate this point:

"Nou ja, t heeft dus mijn manier van denken beïnvloed. Ik heb daar leren communiceren met mensen van verschillende disciplines. Wat ik gebruikt heb al meerdere malen gebruikt hebt bij sollicitaties." (Interviewee 4)

Next, contact with disciplines such as public perception made PhD researchers aware that CCS is more than just a technology. They learned how public perception is vital for such a technology as CCS and how it is part of a whole energy transition. Moreover, interviewees mentioned how this is beneficial for them in their careers. The following quote makes this clear:

"En door alle dingen die ik bij CATO geleerd heb, is het gewoon veel makkelijker om CCS in het hele plaatje van de energietransitie goed te kunnen plaatsen, goed te kunnen beseffen wat de zeg maar de pluspunten en de minpunten zijn en maar ook veel meer weten over wat komt er nou bij opslag kijken en waarom is de publieke perceptie rondom CCS zoals die is. Dus dat soort onderwerpen, dat soort. Ja, dat had ik zonder CATO veel minder begrepen. En dat, ja, dat helpt nu wel in het uitvoeren van de rol die ik nu heb." (Interviewee 9) The research into public perception and increased public controversy influenced the PhD researchers. As said before, the research on public perception inside CATO was visible for fundamental PhD research. Furthermore, multiple interviewees mentioned how the CATO programme and CCS in the Netherlands collapsed due to increased public controversy. Showing their knowledge and interest in the subject of public perception of technology. The following quote illustrates this point:

"Ja, Barendregt ligt daar enigszins aan ten grondslag en er zat dus binnen CATO ook een werkpakket op die in die sociale interactie en hoe dat werkt. En ik was me daar als promovendus heel duidelijk bewust van. En ook nu nog steeds werkt dat door in mijn huidige werk. Dat ik de geo wetenschappen benader niet met een puur technische insteek, maar juist ook met oog voor de geo politieke spanningen die daar omheen kunnen heersen." (Interviewee 4)

Furthermore, PhD students got in contact with the industry. Due to their contact with partner organisations, they would present their results to these organisations or get a sense of what kind of work these organisations do. CATO made these contacts happen and helped get recognition outside the academic world. The following quote illustrates this point:

"Dat soort projecten heeft altijd een laatste symposium of workshop die dan ook open is voor andere mensen en wij zijn toen nog op eigen initiatief ook bij Shell gaan praten bij de afdeling die daar het meest intens mee geassocieerd was. Maar dat was ook enigszins een tactische zet vanuit ons eigen laboratorium zodat ja, dat duidelijk werd dat we wat in ons laboratorium gebeurt van belang is voor Shell....en mijn collega promovendi is uiteindelijk bij Shell gaan werken." (Interviewee 4)

All in all, CATO influenced the PhD researcher to be aware of their surroundings. Next to the standard academic perspective, PhD researchers became more aware of societal and industrial perspectives. These cannot be placed in the current credibility cycle, but these are aspects that influence the career of a PhD researcher and their work as a scientist and, in the end, their credibility. It shows how a mission-driven KES can help open a scientist's individual credibility cycle for other perspectives. Perspectives which help scientists to think more about the impact of their work. This may help produce research and knowledge that can help in today's societal challenges, such as climate change.

Ultimately, if such kinds of scientists are created due to a mission-driven KES, they must keep working on these kinds of subjects. Therefore, every interviewee was asked how their career developed and what kind of subject they are working on now. The following table gives an overview of where the PhD researchers are working now and if they work on a CCS-related subject. Most PhD researchers are still working on CCS or a subject related to CCS (see table 2). This shows that the effects of CATO on the PhD researchers still have some effect on the current field of CCS.

PhD researcher	Organisation	Subject
Interviewee 2	Private firm	Related work to CCS
Interviewee 3	Private firm	CCS
Interviewee 4	Academia	CCS
Interviewee 7	Private firm	Developer
Interviewee 8	PRO	ccs
Interviewee 9	PRO	ccs
Interviewee 10	Academia	Sustainability
Interviewee 11	Private firm	Data scientist
Interviewee 14	Private firm	Related work to CCS

Table 2. Career of PhD researchers

Directionality

The alteration of the credibility cycle shows how a successful mission-driven KES may help solve a directionality failure of a particular sector. Researcher and other actors are all mobilized for one shared goal and all work together towards this shared mission. However, it can also reinforce the directionality failure if the needs and goals of incumbents are too influential in setting the KES's mission (Schot & Steinmueller, 2018). This was present in the case of CATO and CCS. Half of the budget was foreseen by industrial firms and the other half by governmental funds (Van Egmond et al., 2012). NGOs were involved in some decision-making and agenda-setting. However, they did not bring in any funding for the mission-

driven KES of CATO, resulting in a minor influence than industrial firms (Interviewee 13). This may be one of the reasons why public controversy increased during CATO, as NGOs needed to be more involved. All in all, it shows the importance of not only involving industrial partners in a mission-driven KES.

Summary of results

Overall, the results show that CATO can be seen as a mission-driven KES to a large extent. There were a group of heterogeneous actors working towards one system-level goal: new knowledge for CCS. Furthermore, PhD researchers with different backgrounds were brought together by providing a common belief and "group feel". This induced cognitive interdependence between the different researchers and, as a result, a social network. The societal-mission of CATO can be questioned to some extent as societal actors did not have a significant impact on the agenda setting of the programme and the research itself.

CATO induced interactions between the PhD researchers and other actors in the KES. This influenced conversions from staff and equipment, data and arguments. It was easier to share equipment, data and arguments with other researchers and other organisations due to the social network of CATO and because they were all working toward the same shared goal. Finally, CATO induced conversions that cannot be placed in the conventional credibility cycle. PhD researchers became aware of other demands in the industry or society. This meant that the PhD researchers were not only active in the academic credibility cycle by getting academic recognition. But also became interested in receiving recognition from industry and society, see figure 3. In which you can see how outcomes of the research are not only used for academic recognition but also recognition in society and industry. Thus, CATO opened the conventional academic credibility cycle for other paths in industry or society.



Figure 3 Revised credibility cycle

Discussion

In this section, the results of this research will be discussed. First, the theoretical contributions of this study will be elaborated upon. Then, the practical contributions will be discussed. Lastly, limitations and further research directions will be highlighted.

Theoretical contributions

This research has several contributions and implications on the level of theory. First, this study provides further empirical evidence for the literature on knowledge ecosystems and mission-driven knowledge ecosystems described by Thomas & Autio (2020) and Järvi et al. (2018). Literature on KESs and missiondriven KESs still needs a coherent framework, and empirical evidence of dynamics still needs to be provided (Almpanopoulou, 2019). This study tries to combine several studies on KESs in one coherent framework and tests it empirically. The work of Thomas & Autio (2020) on characteristics of a KES, such as heterogeneity and interdependency, was used to formulate characteristics of a mission-driven KES. Furthermore, the research of Järvi et al. (2018) was used to conceptualise the goals of different actors in a mission-driven KES. These characteristics and concepts of a mission-driven KES are present and essential in real-life examples, such as CATO. Heterogeneity, for instance, is an important asset of a mission-driven KES and was one of the main influences on the research of PhD students. PhD students encountered disciplines they would normally not encounter. Furthermore, the social factor of a mission-driven KES in its cognitive interdependence was an important influence. It made it easy for PhD students to reach out to other researchers or organisations in the mission-driven KES to discuss their research or obtain equipment as there was no social barrier. Overall, the characteristics of a mission-driven KES of Thomas & Autio (2020) and Järvi et al. (2018) have been given empirical evidence.

Furthermore, directionality is used to help formalise how missions play a role in a mission-driven KES. This is mainly embedded in the goal characteristic of a KES (Järvi et al., 2018), as different goals are combined into one shared ecosystem goal. It became clear that directionality is an important concept when setting up the mission of a KES. Because a KES consists of a group of heterogeneous actors, many different goals are embedded in the ecosystem (Järvi et al., 2018). This calls for an approach that considers all these goals, such as societal goals, when drafting the mission for the KES. This study, therefore, helped in conceptualising a mission-driven KES.

The literature on the credibility cycle is also further empirically proven and tested. This is mainly done by testing whether the credibility cycle still exists in a different setting, namely, the setting of a missiondriven KES and not a regular academic researcher but a PhD researcher. The credibility cycle still holds in a mission-driven KES. Academic research and recognition remain essential, while at the same time, other kinds of recognition become more important (e.g., industrial and societal). This study contributes to the work of Hessels et al. (2009), who researched the changing contract between society and science with the credibility cycle as a framework. This study contributes to this line of research by showing how a missiondriven KES can help mobilising science for societal goals.

This study used the credibility cycle on PhD researchers. In contrast, most research on the credibility cycle has used it for professional researchers later in their careers (Hessels & van Lente, 2011). This study shows that the credibility cycle still holds for PhD researchers just starting their academic careers. However, there were some discrepancies. For example, PhD researchers do not have to obtain funding at the start of their research as regular academic researchers have to do. Instead, they have to obtain a PhD position. Furthermore, most PhD researchers do not have to hire staff members for their PhD work. Nevertheless, as the credibility cycle is repetitive, they will need to obtain funding through their recognition after finishing their PhD work or later in their academic career. All in all, this study showed that the credibility cycle could be used in other empirical settings than the usual academic ecosystem.

Practical insights

The research also entails practical implications. Policymakers can use this study to see if a mission-driven KES is helpful in mobilising academic research for a societal mission. A mission-driven KES can help with mobilising research for transformative change. It does this by mobilising academic research for a knowledge base needed for a societal mission or problem. It also helps by influencing the researcher itself and influencing its perspective in a positive way for mobilising the researcher for a societal problem in its career.

Some conditions can also be provided for policymakers for a successful mission-driven KES that were noticed in the case of CATO. First and foremost, the KES should inhibit competencies. It is essential to take all actors in the field and incorporate them into the KES. A certain level of coordination is also important for a mission-driven KES to succeed. In the case of CATO, a CATO programme office coordinated and organised the whole KES. Continuity is also crucial for a mission-driven KES. In the case of CATO, this could have been managed better, as after CATO-2, the programme stopped, and the network fell apart. In order to keep the momentum for a particular mission, it is important to incorporate a certain continuity in the KES.

A mission-driven KES such as CATO has several advantages, which were already discussed. However, some downsides of such cooperations must be named as well when directionality is not adequately addressed.

CATO was a mission-driven KES formed around the technology of CCS. CCS is a technology that can help in reducing carbon emissions. However, the technology is questioned for its actual effects on the energy transition. CCS is seen as a technology that conserves the current polluting system and is mainly beneficial for highly polluting industrial firms such as E-ON, Shell and RWE. The involvement of these big industrial firms is significant in CATO. Half of the funding comes from these private actors, which gives them a significant influence on the programme's design. NGOs, such as Natuur&Milieu and Greenpeace, were sometimes involved in the CATO programme, but they did not bring in funding and thus had less influence. This raises the question of whether such partnerships as CATO induce transitions or merely reinforce the current system. This can also be seen in the fact that the CATO programme, which researched public perception, mainly brought unforeseen public controversy around the technology of CCS. CATO got all kinds of actors together, ranging from private firms to NGOs, but in the end, the latter's influence needed to be more significant. Therefore, when policymakers want to formulate mission-driven KESs, they should be careful in giving away too much influence to one type of actor in the system and involve all actors more equally.

A mission-driven KES is a promising tool for policymakers that want to mobilise academic research for a societal mission as research becomes more aimed at the societal problem and researchers become more aware of societal needs. However, policymakers must be careful in giving away too much influence on private actors in setting up these mission-driven KESs.

Limitations

This research has several limitations which must be discussed. First some concerns on the credibility of the research. CATO was active from 2004 to 2012, and most PhD students did their research during this period. This meant that most interviewees spoke about events more than ten years ago. It took a lot of work for some interviewees to recall events or describe them precisely. An interviewee also mentioned that some people tend to over-romanticise things that happened so long ago, remembering the positive parts and forgetting the negative things. Fourteen interviews were conducted, and documents were analysed. In this way, the study tries to give an as robust analysis as possible by using different kinds of data and as much data as possible.

Another limitation of this research is that missions and mission-driven KESs are new concepts. Therefore, mission-driven KESs have yet to be formed that have called and formed themselves as such. CATO is assessed this way, and interviewees mentioned you could look back at it this way. Nevertheless, CATO was not formed with the idea of a mission-driven KES. In the coming years, such mission-driven KESs may

become more popular and easier to study. Future research could therefore focus on mission-driven KESs, which were purposely formed as a mission-driven KES.

Another limitation of the research is the generalisability of the study. The research is based on one case study and is therefore limited in its generalisability to other contexts. The characterisation of the case by characteristics from literature helps in making the research more generalisable to other contexts if they exhibit the same kind of characteristics. Moreover, the case of CATO inhibits most characteristics of a mission-driven KES, such as heterogeneity, interdependencies and coordination.

Future research

There are interesting avenues for future research on mission-driven KESs and the credibility cycle. First, there is still more research needed to conceptualise a mission-driven KES. Multi-case studies can be carried out to increase the empirical evidence on mission-driven KESs. It may be interesting to see if the advantages and disadvantages of CATO are observable in other cases as well.

Other research could focus on the continuity of mission-driven KESs, such as CATO. Multiple interviewees mentioned that the cancellation of CATO-3 took away the momentum for CCS research and demonstrations in the Netherlands. It might be interesting to see the reasons for this and how a mission-driven KES can be successfully continued. This may happen by continuing the mission-driven KES itself or shaping a new kind of KES which requires less input but keeps the network alive. Research into this subject is important as the output of a mission-driven KES must be actively used and continued.

Future research can also further examine the credibility cycle in the social and industrial context. The relationship between social, industrial and academic credibility and recognition is an interesting research lens. Future research could, for instance, perform a study on how these three types of credibility influence the researcher and each other.

Other research could study the directionality of KESs further. Some insights were given already in this research on the fact that all actors, not just private actors, need to be incorporated in the setting of the mission. Research could further study this principle and research how this can be done in practice and how for example funding has influences on this process. In the case of CATO the ecosystem was funded for 50% by private actors, giving them a high influence in the agenda setting. It can be researched how society or NGOs can counteract this while providing no funding themselves.

Conclusion

In this section, the main conclusions of this research are given.

In this study, we did a case study on the mission-driven KES of CATO. First, we started with a document analysis of articles that analysed the ecosystem of CATO. Second, we interviewed a coordinator and director of CATO to get an overview of the dynamics in the mission-driven KES. Third, we interviewed PhD researchers and their supervisors on their experiences of doing their PhD work in such an ecosystem. Finally, we examined what kind of characteristics of a mission-driven KES influence certain conversion steps of the credibility cycle.

The research answers the following research question: What is the influence of a mission-driven KES on the credibility cycle of academic researchers?

The answer to the research question is twofold. First, it influences the academic credibility cycle of an individual researcher by inducing cooperation in several conversion steps of the credibility cycle. Second, the mission-driven KES of CATO opens the academic credibility cycle to societal and industrial recognition.

Cooperation between actors of CATO was induced via a couple of mechanisms of a mission-driven KES. The heterogeneity of the ecosystem meant that actors and researchers could learn things from each other and from actors they would typically get less in contact with. The shared goal of the ecosystem meant that they were all working towards increasing knowledge for CCS. The cognitive interdependencies of an ecosystem meant that a social network was created, making it easier to contact other researchers and organisations. All in all, the research of PhD students was more aimed at the mission of mission-driven KES and more cooperation improved the research.

The credibility cycle of researchers opened up to societal and industrial recognition due to a couple of mechanisms of a mission-driven KES. The directionality of the ecosystem meant that more needs and goals than just academic needs and goals were important. Due to the research into public opinion, PhD researchers in, for example, chemistry were activated to think about the needs of society. The heterogeneity of the ecosystem also meant that researchers came in contact with industrial partners. Some PhD researchers did their study for an industrial partner or came in contact with them on CATO days or field trips, which induced awareness of the needs of industrial actors. All in all, the normal academic credibility cycle of the PhD researcher changed to a credibility cycle which incorporates societal and industrial needs.

Overall, this study can be used as explorative research on a mission-driven KES and the influence on the credibility cycle of PhD researchers in such an ecosystem. A mission-driven KES, such as CATO, influences the research that is carried out. Research is more closely aligned with the goals of the ecosystem, and collaboration between a diverse set of actors is induced. Moreover, other kinds of researchers are created by broadening the knowledge of PhD researchers and by making them aware of industrial and societal needs. However, it must be closely monitored if such a mission-driven KES also positively impacts society. Because the formulated mission and goal of the KES can become influenced too much by private actors that provide the funding, resulting in a directionality failure. Nevertheless, if the mission of the KES is truly aligned with the needs of society, a mission-driven KES can be of great help in pushing research and researchers in the desired direction.

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Appendix A Interview Guides

Interview guide 1 PhD researcher Dutch

Confidentiality and permission:

- Bedankt dat ik dit interview mag afnemen.
- Ik zou het interview graag willen opnemen, is dat oke?
- Het interview zal worden gebruikt in mijn thesis onderzoek aan de Universiteit Utrecht en door het Rathenau Instituut waar ik stage loop, en bij onderzoek bij de universiteit Leiden van mijn begeleiders.
- Uw naam zal geanonimiseerd worden en ik heb een informed consent formulier wat ik u graag zou laten invullen.

Introduction of the subject:

- Ik doe de master innovation sciences aan de universiteit Utrecht en ben sinds september begonnen aan mijn scriptie.
- Daarnaast voer ik deze scriptie uit voor het rathenau instituut, waarbij Jorrit Smit en Laurens Hessels mijn begeleiders zijn.
- Ik doe onderzoek naar de mobilisatie van fundamenteel onderzoek voor maatschappelijke opgaves.
- Wij zien CATO als een interessant voorbeeld hiervan en voeren nu dus interviews uit met deelnemers aan CATO.

Theme 1 Role of participant in CATO:

- Kunt u eerst zelf eerst iets kort vertellen, in een paar zinnen, over uw PhD onderzoek bij CATO?
- Waar hebt u het onderzoek uitgevoerd?
- Wat is uw betrokkenheid bij specifiek CATO?
- Hoe zou u zelf CATO beschrijven?
- Heeft u samen gewerkt met een partner organisatie binnen CATO?
- Waarom was het voor jou belangrijk om partner contact te hebben? Of vond uw begeleider het belangrijk?
- Hoe ervaarde u deze samenwerking met andere organisaties en hoe verschilde dit tussen organisaties, bv. Shell/TNO? Zorgde dit nog voor spanningen?

Theme 2 Goal of CATO

- Hoe zou u zelf de missie van CATO omschrijven?
- Hoe kijkt u nu zelf terug op deze missie?
- Had de achterliggende missie en doel van het programma ook betrekking op uw dagelijkse onderzoekswerk, zo ja op welke manier?
- Heeft de 'controverse' rond CCS in het publieke debat een rol gespeeld?
- Heeft u of hebben andere omheen hier nog actief een rol in gespeeld?

Theme 3 Research process

Toelating

• Waarom besloot u om te solliciteren voor een PhD bij CATO?

- Speelde de missie hierbij een rol of waren er andere redenen?
- Hoe bent u bij CATO terechtgekomen?
- Wat denkt u dat u geschikt maakte voor deze promotieplek?
- Wat waren naar uw idee de eisen om aan te voldoen om aangenomen te worden binnen CATO?
- Heeft u financiering gekregen vanuit CATO voor uw PhD werk, zo ja verschilde dit van andere PhD posities?
- Was de financiering bij CATO anders bij andere promovendi die niet binnen CATO werkte?
- Wat voor verplichtingen brengt dit nog mee, kijkend naar de missie?
- Heeft de financiering meer mogelijkheden gegeven?
- Heeft het type financiering nog invloed gehad op uw beslissing om deel te nemen aan CATO? Onderzoeksperiode
 - Hoe is de onderzoeksvraag tot stand gekomen?
 - Wie heeft hier een rol in gespeeld?
 - Verschilde de invloed van verschillende partnerorganisaties?

Faciliteiten en instrumenten

- Waar heeft u uw onderzoek uitgevoerd? (alleen uni, of ook bij partners, buitenland) Wat motiveerde u om (ook/niet) gebruik te maken van deze andere faciliteiten?
- Heeft u bepaalde hulpmiddelen voor bijvoorbeeld laboratoria nodig gehad tijdens uw onderzoek bij CATO en in hoeverre kwam de missie van CATO hierin terug of de deelname van u aan CATO?
- Had u bepaalde mensen voor u werken in bijvoorbeeld laboratoria en hoe ging de selectie van deze personen?

Samenwerkingen

- Heeft u samengewerkt met andere onderzoekers, zo ja was dit met onderzoekers van CATO, de universiteit, of anderszins?
- Wat hield deze samenwerking in?
- Hoe ervaarde u deze samenwerking, in relatie tot de missie en KES?
- Wat voor activiteiten heeft u ondernomen met andere onderzoekers (met name: promovendi) binnen CATO?
- Hoe ervaarde u deze momenten?
- Bedrijven binnen CATO
- Voelde u zich onderdeel van CATO hierdoor?
- Wat zorgde hiervoor?

Uitkomst

- Waar besprak je, met wie, en hoe ging het bespreken van tussentijdse onderzoeksresultaat bij CATO?
- Wat voor rol speelde uw partnerorganisatie hier nog in?
- Hoe besloot je waar je ging publiceren, wanneer was het klaar, wie bepaalde dit?
- Was er een focus op bepaalde soort onderzoeksresultaten?

- Wat voor soort reacties kreeg u binnen CATO op uw werk? En buiten CATO?
- Verschilde deze reacties, en waarom wel/niet denkt u?
- Hoe is uw verdere carrière verlopen na CATO?
- Waar werkt u nu?
- Wat voor invloed heeft uw PhD werk gehad op uw latere carrière? Denkt u dat deelname aan CATO van belang is geweest (mbt onderwerp, netwerk, zichtbaarheid...)?
- Heb je vervolgens nog aan het onderwerp door gewerkt en heb je dit nog op andere platformen gepubliceerd, in de krant bijvoorbeeld. En waarom?

Ending/summary:

- Samenvatting van het interview
- Heeft u nog onderwerpen waar wij het nog niet over hebben gehad maar volgens u wel belangrijk zijn?
- Heeft u vragen voor mij?
- Bedanken voor het interview

Interview guide 2 supervisor Dutch

Confidentiality and permission:

- Bedankt dat ik dit interview mag afnemen.
- Ik zou het interview graag willen opnemen, is dat oke?
- Het interview zal worden gebruikt in mijn thesis onderzoek aan de Universiteit Utrecht en door het Rathenau Instituut waar ik stage loop, en bij onderzoek bij de universiteit Leiden van mijn begeleiders.
- Uw naam zal geanonimiseerd worden en ik heb een informed consent formulier wat ik u graag zou laten invullen.

Introduction of the subject:

- Ik doe de master innovation sciences aan de universiteit Utrecht en ben sinds september begonnen aan mijn scriptie.
- Daarnaast voer ik deze scriptie uit voor het rathenau instituut, waarbij Jorrit Smit en Laurens Hessels mijn begeleiders zijn.
- Ik doe onderzoek naar de mobilisatie van fundamenteel onderzoek voor maatschappelijke opgaves.
- Wij zien CATO als een interessant voorbeeld hiervan en voeren nu dus interviews uit met deelnemers aan CATO.

Theme 1 Role of participant in CATO:

- Kunt u eerst zelf eerst iets kort vertellen, in een paar zinnen, over uw werk als begeleider bij CATO?
- Wat is nou precies uw rol?
- Heeft u samen gewerkt met partner organisaties binnen CATO?
- Wat voor ander werk heeft u gedaan binnen CATO?
- Hoe zou u zelf CATO beschrijven?

- Heeft u samen gewerkt met een partner organisatie binnen CATO?
- Hoe ervaarde u deze samenwerking met andere organisaties en hoe verschilde dit tussen organisaties, bv. Shell/TNO? Zorgde dit nog voor spanningen?

Theme 2 Goal of CATO

- Hoe zou u zelf de missie van CATO omschrijven?
- Hoe kijkt u nu zelf terug op deze missie?
- Had de achterliggende missie en doel van het programma ook betrekking op uw dagelijkse werk bij CATO, zo ja op welke manier?
- Heeft de 'controverse' rond CCS in het publieke debat een rol gespeeld?
- Heeft u of hebben andere om u heen hier nog actief een rol in gespeeld?

Theme 3 Research process

Toelating

- Waarom besloot u begeleider te worden bij een PhD onderzoek binnen CATO?
- Weet u hoe de PhD posities zijn gevuld binnen CATO?
- Weet u wat voor soort eisen er waren om PhD onderzoek te gaan doen binnen CATO?
- Heeft u financiering gekregen vanuit CATO voor uw werk als begeleider of andere werkzaamheden binnen CATO?
- Weet u of de financiering van promovendi binnen CATO anders was dan op andere promovendi plekken? En in hoeverre speelde de missie van CATO hierin een rol?

Onderzoeksperiode

- Hoe is de onderzoeksvraag van het PhD onderzoek tot stand gekomen?
- Wie heeft hier een rol in gespeeld?
- Verschilde de invloed van verschillende partnerorganisaties?

Faciliteiten en instrumenten

- Waar voerde de promovendi hun onderzoek uit? (alleen uni, of ook bij partners, buitenland)
- Hoe maakte promovendi gebruik van de faciliteiten of bepaalde instrumenten die er waren op de universiteit of bij partners? en in hoeverre kwam de missie van CATO hierin terug of de deelname van u aan CATO?

Samenwerkingen

- Wat voor samenwerkingen waren er tussen PhDers onderling, en verschilde dit voor PhDers binnen en buiten CATO?
- Wat hield deze samenwerking in?
- Hoe kwam de missie van CATO hierin terug?
- Wat voor activiteiten zijn er ondernomen met verschillende PhDers binnen CATO?
- Hoe ervaarde uzelf of uw PhDers deze momenten?
- Wat voor activiteiten zijn er ondernomen met partnerorganisaties?

Uitkomst

- Hoe ging het bespreken van tussentijdse resultaten bij CATO? Waar en met wie werd dit allemaal besproken?
- Wat voor rol speelde partnerorganisatie hier in?

- Hoe besloot de PhDer en u waar jullie gingen publiceren, wanneer was het klaar, wie bepaalde dit?
- Was er een focus op bepaalde soort onderzoeksresultaten?
- Wat voor soort reacties kregen u en uw PhDers op jullie werk binnen CATO? En buiten CATO?
- Verschilde deze reacties, en waarom wel/niet denkt u?
- Hoe is uw verdere carrière verlopen na CATO en heeft u zicht op de verdere carrière van uw promovendi?
- Waar werkt u nu?
- Denkt u dat de deelname aan CATO van belang is geweest voor de promovendi, mbt tot het onderwerp, netwerk en hun zichtbaarheid.

Ending/summary:

- Samenvatting van het interview
- Heeft u nog onderwerpen waar wij het nog niet over hebben gehad maar volgens u wel belangrijk zijn?
- Heeft u vragen voor mij?
- Bedanken voor het interview

Appendix B Coding Scheme

Mission-driven KES

Heterogeneous actors
 Academia Different disciplines Public Research Organisation Private actors Civil society
Relations
 Social network New/excisting relations Consciously/subconsciously formed relations
Knowledge
 Agendasetting Creation Sharing Development Dissemination
Goal
 Individual goals Organisational goals Ecosystem goals Societal goals
Exogeneous factors
Public controversy

Credibility cycle

Money
Staff and equipment
Data
Arguments
Articles
Recognition
Alternative component

Appendix C Informed consent form

In this study we want to learn about the mobilization of fundamental knowledge for societal missions in the context of the research program of CATO. Participation in this interview is voluntary and you can quit the interview at any time without giving a reason and without penalty. Your answers to the questions will be shared with the research team. We will process your personal data confidentially and in accordance with data protection legislation (the General Data Protection Regulation and Personal Data Act). Please respond to the questions honestly and feel free to say or write anything you like.

Everything you say or write will be confidential, and anonymous. This means that we do not ask for your name, and no one will know which respondent said what.

I confirm that:

- I am satisfied with the received information about the research;
- I have no further questions about the research at this moment;
- I had the opportunity to think carefully about participating in the study;
- I will give an honest answer to the questions asked.

I agree that:

- the data to be collected will be obtained and stored for scientific purposes;
- the collected, completely anonymous, research data can be shared and re-used by scientists to answer other research questions;

I understand that:

• I have the right to see the research report afterwards.

Do you agree to participate? o Yes o No

Signature Interviewer:

Signature interviewee: