Partnering for Transformation - exploring the concept of Transformative Academic Institutions

Smith, Madeline; Canto-Farachala, Patricia; Wise, Emily

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Challenges and solutions for fostering university-industry engagement, entrepreneurial & innovative universities and collaborative innovation

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Effectiveness of Knowledge sharing between the University of Applied Sciences and SMEs

Taru Mäki [1]

[1] Seinäjoki University of Applied Sciences

Abstract

Interaction and cooperation between universities and enterprises is important for the development of skills and the economy. Most of previous research has targeted the transfer of knowledge between large industrial companies and large universities and has therefore largely concentrated on technology transfer and patents (Schartinger, Rammer, Fitzer & Fröhlich, 2002; Mathieu, 2011; Hermans & Castiaux, 2007). According to Anatan (2013) and Beckers and Bodas Freitas (2008), there is a clear gap in the research on dyadic knowledge transfer. Research should focus on mutually beneficial cooperative in the interaction that takes place, e.g., through internships, exchanges, and other personal contacts (Schartinger, Rammer, Fischer & Fröhlich, 2002; Mathieu, 2011; Muscio, 2007).

The aim of this study was to examine how knowledge is shared between universities and SMEs, as well as the main impacts and new opportunities of this interaction for SMEs in the course of time. The effectiveness of interaction can be verified by analysing concrete outputs, and how the company's operations have changed in the long term.

In this study, the theoretical framework for knowledge sharing consists of combining three previously created models together in a new, innovative way. When looking at the interaction and knowledge sharing between a university and an SME, the 5C model developed by Ternouth et al. (2012) was adapted. The most important model of the study is the verification of the effectiveness of knowledge sharing, with Holi et al. (2008) as the frame of reference for the ecosystem model of knowledge transfer impacts. Besides Holi's model, the approach for defining new opportunities for SMEs was used (Rosli et al., 2018).

The research data consisted of companies that had participated in two different Research and Development projects. The data consisted of a total of 54 cooperation events at eleven SMEs. On average, the companies cooperated in four to six ways, which is much compared to the size of the SMEs. The content analysis of the study was performed using the Gioia analysis.

The effectiveness of knowledge sharing in cooperation was examined from three different perspectives: the concrete outputs, new opportunities, and long-term effectiveness that had emerged. The data revealed a surprisingly significant amount of effectiveness in each aspect. During the cooperation, concrete outputs were generated by 29 % of the events. New opportunities were opened for SMEs at 59 % of the events. Long-term effects were identified after 63 % of the events.

During this study, a model was developed for the effectiveness of knowledge sharing during the cooperation between universities and SMEs. At the same time, an understanding of the ability of SMEs to exploit knowledge increased, and their ways to improve the effectiveness of interactions were developed.

Keywords

Knowledge sharing, effectiveness, SMEs, University of Applied Sciences

1 Introduction

In previous studies, by far the most challenging and least studied area of cooperation and interaction between universities and SMEs is the measurement and verification of the results of interaction and knowledge sharing. Research has shown that knowledge sharing measures have not had a direct financial impact on companies (Holi et al, 2008; Anatan 2013). On the other hand, it has also been possible to show that a small number of new products or processes could not have been developed, or would have been developed much later, without university cooperation (Beckers & Bodas Freitas, 2008; Konttinen, Suvinen & Nieminen, 2009). However, SMEs and universities can both benefit from the interaction and may lead to, e.g., new innovations and opportunities to create new development projects or networks (Bercovitz & Feldmann, 2006; Konttinen et al, 2009; Mathieu, 2011; Rosli et al, 2018). Effectiveness can also be measured at the societal level, such as the number of students graduating and employed in the area, the financial impact on the area, the intellectual impact, or the imaginary impact on the area (Kalika et al., 2016; Mourão & Borges-Andrade, 2013). In this study, the key models used are the Model of impact in the knowledge transfer ecosystem (Holi et al, 2008) and the classification of the increase in new opportunities as defined by Rosli et al. (2018).

The result of this study is an analysis of the effectiveness of knowledge sharing in interaction between universities and SMEs from an SME perspective. The review is more extensive than in previous studies. Mutual interaction and a clearer focus on the role of SMEs are important for the success of cooperation. Previous research has emphasized the role of universities in both the design and implementation of knowledge transfer and know-how, and in this case the opportunities of utilizing knowledge by companies are given less attention.

The key elements in the interaction between universities and companies are knowledge sharing, absorptive capacity, learning through interaction, and the impact and new opportunities arising from knowledge sharing and interaction. The theoretical framework is based on the three dimensions: Knowledge Sharing, Absorptive capacity and Learning, and Exploitation and Effectiveness.

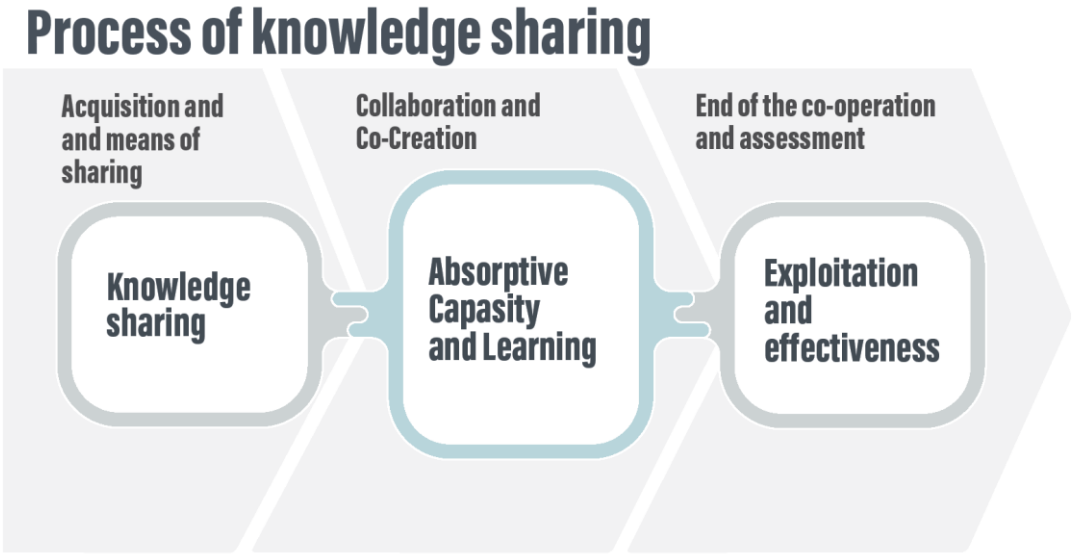

Fig. 1: Theoretical Framework of the research

In this study, the theoretical framework for knowledge sharing consists of combining five previously created models together in a new, innovative way. The classification of shared knowledge uses a wide-ranging classification model utilized by several researchers. When looking at the interaction and knowledge sharing between a university and SME, the 5C model developed by Ternouth et al. (2012) was adapted. A key component of knowledge sharing is the knowledge-receiving model (Zahra & George, 2002) and the learning model (Chen et al, 2019). The fourth and most important model of the study is the verification of the effectiveness of knowledge sharing, with Holi et al. (2008) as the frame of reference for the ecosystem model of knowledge transfer impacts, and Rosli et al. (2018) as the fifth approach for defining new opportunities for SMEs.

The study examines how knowledge is shared between universities and SMEs, and what the impacts and new opportunities of this interaction are for SMEs in the long term. The effectiveness of the interaction can be verified by analyzing concrete outputs and how the company's operations have changed in the long term. In addition, the practices and absorptive capacity of SMEs in utilizing knowledge shared in cooperation are examined.

The aim of the study is to find out

- the ways of sharing knowledge and know-how in the interaction between universities and SMEs
- the new opportunities and longer-term effectiveness they provide for SMEs.

In addition, the aim is to find out the practices and capacity of SMEs to use the information shared in cooperation between universities and SMEs.

2 Literature review

Previous research on the types of collaboration and knowledge or know-how transfer focuses to quite a large extent on technology transfer and patents from universities to industry (Schartinger et al, 2002; Beckers & Bodas Freitas, 2008; Mathieu, 2011). According to Hermans and Castiaux (2007), transfer of knowledge has also been studied mainly in the form of publications and patents as a one-way transfer of knowledge from universities to industry. Instead, small companies can take advantage of it to a lesser extent than than large companies or industry units (Cohen, Nelson & Walsh, 2002). However, in both universities' and companies' experience, the best means of transferring knowledge and know-how are e.g., personal discussions and informal contacts, and the employment of graduates by the company (Mathieu, 2011; Muscio, 2007). Previous studies of collaborative practices have found that the research should focus more on the transfer of knowledge and know-how through internships, exchanges, start-ups, and other personal contacts. (Schartinger et al, 2002) According the previous research, there is clear a gap in two-way (dyadic) cooperation and interaction (Anatan 2013; Beckers and Bodas Freitas, 2008). Research should focus on mutually beneficial cooperative activities. The co-operation is jointly planned and implemented, for example in the form of joint research. The cooperation should also continue after a longer period of research or another joint process. (Pertuze, Calder, Greitzer & Lucas, 2010; Hermans & Castiaux, 2007) Research could also dig deeper into the organization and management of university-business cooperation. (Perkmann, 2007).

Cooperation and interaction between universities and SMEs should try to pursue broad effectiveness. The SME must be capable of receiving information from the university and utilizing the information shared. The key to success is that, before collaboration in the real joint action phase, there has already been cooperation between the company and the university in the planning and pilot phases (Buganza et al, 2014). In previous research, measuring effectiveness has been found to be challenging. In many cases, the transfer of know-how from universities to companies is not due to performance, but can help the company's actors to produce, for example, economic growth (Holi et al, 2008). There are various definitions of effectiveness, e.g. The RDCE model (Lakpetch & Lorsuwannarat, 2012), the chain of influence thinking (Rajahonka, 2013), or the ecosystem model of the effects of knowledge transfer (Holi et al, 2008).

It is important for universities to create markets, disseminate research results and experimentation with research data in practice and further development of knowledge (Intzesiloglou et al. 2010; Corillon & Mahaffy 2012). Companies, on the other hand, seek financial benefits from cooperation (Anatan 2009), benefit from working with experts, increasing one's own level of knowledge and improving processes (Mathieu 2011) and identifying the company's potential. Both parties saw the new advantage in networking as an advantage and the opportunity to participate in further projects.

Colleges also benefit from interaction with companies. In general, the value of basic research in particular is difficult to verify (Bercovitz & Feldmann 2006; Mathieu 2011). In business cooperation, the ability and readiness of higher education institutions to solve problems faster

together with companies develops (Anatan 2013). Companies interact with universities to provide different information than would otherwise be available to them. New knowledge gained through interaction can lead to new innovations and increase opportunities for companies e.g., new innovations. (Bercovitz & Feldmann 2006; Konttinen et al, 2009)

According to research, mutual transparency is a prerequisite for cooperation as well as respect for the working environments, goals and ethics of both parties and constraints. (Corillon & Mahaffy 2011) What matters is who invented it the idea of a joint venture. In this case, it is determined what the competencies of the different actors will be developed. (Hermans & Castiaux 2007) The goals of both parties must be defined, and cooperation must be flexible and confidential. As a result of the co-operation, both parties will increase their expertise and the value of the co-operation will increase and sustainability will improve. (Corillon & Mahaffy 2011) Interaction and collaboration require a strong commitment from both parties and become relevant long-term cooperation and trust (Hermans & Castiaux 2007)

3 Research methodology

This study is based on a comprehensive literature review of knowledge transfer and sharing research, the effectiveness of knowledge transfer and sharing, and what is known about knowledge transfer and sharing between universities and companies. The aim has been to create a thorough understanding of the research topic for the researcher and, at the same time, to create a theoretical framework for the study.

Research data consisted of eleven interviews of SMEs. The data is limited to selected SMEs in the Region of South Ostrobothnia, where the interviews were conducted. The data was collected by interviewing one person from each company, mainly from the company's management. The interview was conducted with the semi-structured interview method. SME companies involved in two different research and development projects were included in the sample. The data consists of altogether 54 cooperation events at eleven SMEs. On average, the companies cooperated in 4 to 6 ways, which is much compared to the size of the SMEs under study.

The research strategy is content analysis of the interview data collected in the study. In the data analysis, the models highlighted in the theoretical framework were used, combining them into a broader entity to cover the entire knowledge sharing process. The data analysis was performed with selected research data.

The study used critical incident techniques (CIT) as the background data collection method. The method is of high quality and very flexible. The data was collected from the respondents' point of view, and they describe the events in their own words. Relevant experiences can be either negative or positive. Only significant events are covered in the interview, and the events always take place in the past.

In this study, the relevant events that took place at the company were collected as part of the data of the semi-structured interview under study to support the development activities pursued by the company. Relevant events are classified here according to the main method of the study, the Gioia analysis.

The content analysis of the data was performed using the Gioia analysis. The Gioa method was developed by Gioia and Chittipeddi (1991). The Gioia analysis first gathers the first-stage concepts from the interviews, which can be, for example, 50–100 concepts from ten interviews. The concepts of the first stage are therefore data-driven. Then, similarities or differences are sought from the data, and they form the second-phase themes, classified under a broader theme related to the theoretical framework. At this stage, special attention is paid to the themes or emerging concepts that have not been adequately addressed in previous studies or in the literature. After the second phase, the themes are still analysed in order to form overall dimensions of broader categories or themes. (Gioia et al, 2012)

4 Results

The effectiveness of knowledge sharing in cooperation was examined in three different ways, i.e., in terms of 1) concrete outputs, 2) long-term effectiveness and 3) new opportunities that had emerged. The data revealed a surprisingly significant amount of effectiveness in each aspect. During the co-operation, concrete outputs were generated at a total of 22 events (29 percent of the co-operation events), and they were evenly distributed among the industries. A total of 32 new opportunities were opened to SMEs at 59 percent of the co-operation events, of which 69 percent were closest to the development of useful networks in the tourism sector. The long-term effects identified as a result of the co-operation totaled as many as 34 (63 percent of the co-operation events) and were evenly distributed across industries.

The most visible part of 1) the concrete results were the outputs related to Digitalization. The other two overall dimensions, Visible Development for Customers and Development of the Company's Processes, are also partly related to this, as the development of digitalization was also part of those outputs.

When looking at 2) the longer-term effectiveness of the cooperation, the effect is more abstract, but more widely seen within the company. Digitalization is related to these overall dimensions in some way, but the most significant area is the development of the Company's operating culture, which includes impacts, i.e., on the information systems, processes used, and the quality system. The second largest impact is on the development of competence and management, in which case the effects also fall on the competence of personnel.

In the third dimension 3), new opportunities for SMEs, the greatest impact was achieved in the development of useful networks for university actors and other companies. Both the development of networks and the creation of new R&D projects were recognized as the immediate results, but their effects will be felt in the longer term in the coming years. This third dimension, the new opportunities for SMEs, is the most difficult to link to the others. The creation of and participation in new R&D projects is clearly linked to the further development of digitalization and to the themes that companies want to develop in the longer term.

The result of the study is a model describing the effectiveness of knowledge sharing during the interaction between universities and SMEs.

In this study, the theoretical framework for knowledge sharing was formed by examining five previously developed models in response to research questions. The models have not been considered together in previous studies, although all of them are linked to the sharing or transfer of knowledge and know-how.

The broad classification model for shared knowledge and knowledge used in the distribution of research data and by several previous studies (Perkmann, 2007; Beckers & Bodas Freitas, 2008; Mathieu, 2011) is well suited for use in this type of research. In Finland, the co-operation of higher education institutions with companies is very diverse. The classification highlighted a few forms of co-operation that were clearly not present in co-operation with SMEs. They were participation in conferences, publications, equipment sharing and spin-off companies, which are more suitable for cooperation in large-scale collaborative projects between large companies and universities. On the other hand, the interviews brought out some forms of co-operation that suit SMEs well and that have been shown up by previous studies, too (Mathieu, 2011; Muscio, 2007). These include informal interaction, co-operation in research and development projects, participation in events organized by the university, and co-operation with students. The clearest differences compared to previous research were that 1) the interviewees themselves had studied at the university, 2) the staff of the SME studied at the university, and 3) co-operation with the Regional University of Applied Sciences. These three forms of cooperation do not appear in previous research.

The second theoretical model used was the 5C model developed by Ternouth et al (2012), describing good practices in knowledge transfer. It can be stated from the data that information sharing and cooperation between SMEs and universities takes place at three levels, namely the identification of business opportunities (awareness), joint identification between the university and the company and joint design (acquisition), and joint creation (internalization and transfer). As in previous studies (e.g., Sitra, 2007; Tekes, 2006), co-operation does not take place during the commercialization phase. In this connection, the wishes of SMEs that clearly emerged from the data were that they wanted to continue to co-operate for a longer period of time, so that the utilization of shared knowledge would also become more widespread.

The most important research topic is the effectiveness of knowledge sharing and cooperation specifically at SMEs. The most significant theoretical contribution of the study arises from a combination of examining the effectiveness of knowledge sharing and cooperation in two previously created models and thus examining effectiveness in three different areas: in terms of concrete outputs, new opportunities, and longer-term effectiveness. The two models selected for consideration in the theoretical framework are of very different types: the ecosystem model of the effects of knowledge transfer (Holi et al, 2008) and identifying new opportunities for SMEs (Rosli et al, 2018). The Model of impact in knowledge transfer ecosystem has been used in the past to measure knowledge transfer effectiveness from a university perspective when used in the present study to describe effectiveness from an SME perspective. The model was also well-suited for companies for measuring different aspects of effectiveness. Roslin et al (2018), on the other hand, had previously used the model of new opportunities for SMEs in the context of SMEs, with similar results. New opportunities were identified in 59 percent of the cooperative relationships, their share being as high as 76 percent in Roslin et al.'s (2018) study.

However, the model clearly brings out a new dimension to measuring the effectiveness of cooperation. And when these two models were used in parallel in the present study, a broader picture of the effectiveness of collaborative knowledge was obtained (see Table 21 and Figure 19). The result is a new wide-ranging approach to describing the effectiveness of university-SME co-operation. The model binds the previously most fragmented aspects of the effectiveness of knowledge sharing into a larger whole and highlights the importance of long-term cooperation between actors. It also creates a new perspective, according to which, in addition to measuring measurability, effectiveness can also be a new opportunity to deepen and continue the interaction between an SME and a university.

5 Discussion and recommendations

The present study can be seen as a contribution to previous research and, in practice, to SMEs that have been its target group. In this study, the theoretical framework for knowledge sharing was formed by examining five previously created models in response to the research questions. The models have not been considered together in previous studies, although they are all linked to the sharing or transfer of knowledge and know-how. The theoretical framework of this study is more broadly related to interaction and cooperation between universities and SMEs, and, more specifically, to previous research on the transfer of knowledge and know-how, as well as to previous research on the learning ability and absorptive capacity of SMEs. The broad classification model for shared knowledge and knowledge used in the distribution of research data and by several previous studies (Perkmann 2007; Beckers & Bo das Freitas 2008; Mathieu 2011) is well suited for use in this type of research in Finland, where the co-operation of higher education institutions with companies is very diverse.

The second theoretical model used was the 5C model developed by Ternouth et al (2012), describing good practices in data transfer. It can be stated from the data that knowledge sharing and cooperation between SMEs and universities takes place at three levels, namely the identification of business opportunities (awareness); joint identification between the university and the company and joint design (acquisition) and joint creation (internalization and transfer). As in previous studies (e.g., Sitra 2007; Tekes 2006), co-operation does not take place during the commercialization phase. In this connection, the wishes of SMEs that clearly emerged from the data were that they would like to continue to co-operate for a longer period of time, so that the utilization of shared knowledge would also become more widespread.

For SMEs, the study pointed out that, in reality, cooperation with universities generates both concrete outputs and, consequently, immediate effectiveness and, on the other hand, longer-term effectiveness. Its verification and the development of the continuity of cooperation would benefit both parties. The most important preconditions for successful cooperation were mutual trust, visible development for customers, and the company's vision of cooperation. Correspondingly, a challenge in cooperation is the slowness of cooperation processes, the different views of the actors, and the lack of time for cooperation at the company. From the point of view of both parties, the sharing of information and the ability to receive it are improved by knowing the other party's operating methods. It is an advantage for the company if the

entrepreneur themselves has a university degree, thus having a vision of how the university operates.

The university should share a common vision of the cooperation with the company, select competent, networked project managers, and regularly review feedback on the company's needs. The interviewees stated that it is important for the success of the cooperation that the university actor have previously worked at companies or in business. In this case, he can already from the company's point of view.

For SMEs, the most useful thing would be to continue cooperation for the implementation phase. This study showed that cooperation often produced good operating models or tools, but then their utilization depends on the SME's own expertise. In this study, we developed a new model that emphasizes the continuation of knowledge sharing and cooperation between universities and SMEs, and thus the achievement of longer-term effectiveness. In the model, a new phase is Aftercare and Continued Collaboration, which makes it possible to achieve longer-term effectiveness.

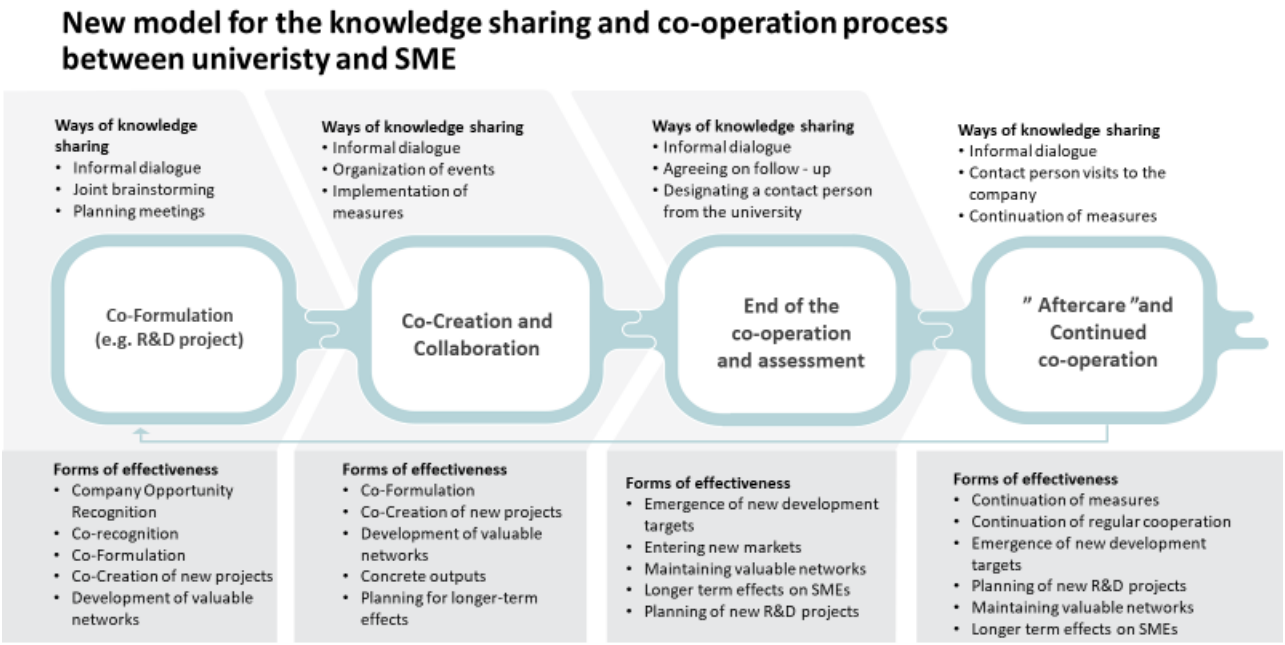

Fig. 2: New model for the knowledge sharing and co-operation process university and SME

6 Conclusion

This study confirmed the results of previous studies on knowledge sharing, but also highlighted the new observations regarding the sharing of information in cooperation between SMEs and universities of applied sciences. The main result was a combination of two models used to measure effectiveness, as a clearer picture was obtained of the effectiveness of information sharing.

The companies stated that the information shared was in an acceptable format and distributed in an appropriate amount at a time. Important for learning was the entrepreneurs' own enthusiasm for learning, and their level of education. Particular attention should be paid to continuing cooperation in the practical implementation of the results, models and practices achieved by the SME or to supporting the recovery or the commercialization process. In practice, universities should have a number of experts, who could be involved in the implementation phase at the SMEs.

It would be very interesting to carry out a survey on a large number of SMEs in Finland in order to find out whether the results could be generalized in this respect. It would also be important to obtain data from different countries for comparison to allow the dissemination of good practices to Finland, as well.

It would also be interesting to get into practice in this study established good practice in business cooperation and then conduct a follow-up study on their effects on knowledge and on the effectiveness of knowledge transfer.

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Exploring Missing Links Between International University Collaboration and International Industry Collaboration

Yuzhuo Cai [1]

[1] Faculty of Management and Business, Tampere University

Abstract

This paper theoretically conceptualises and empirically explores the role of international university collaboration in building transnational university–industry co-innovation networks (TUICNs) in the EU–China context and suggests a new model of international innovation cooperation. The theoretical framework was constructed by synthesising insights from social network theory and institutional theory. The empirical exploration was based on an analysis of interviews with 18 actors engaged in EU–China innovation cooperation. The findings suggest that international university collaboration could contribute to international industry collaboration and, therefore, to the development of TUICNs by 1) matching suitable industrial partners, 2) building trust between them, 3) giving industrial actors access to new resources, (4) enhancing the reputations of international companies in their cooperation countries, and (5) creating innovative business collaboration models. The study also addresses the following paradox in innovation studies: although the vital role of universities in national/regional innovation systems has been widely studied and the global interconnectedness of innovation networks is generally acknowledged, little attention has been given to universities' engagement in transnational innovation (eco)systems. Based on the findings, recommendations for policymakers, universities and companies are provided in light of the shifting balance of challenges and opportunities presented by China to the EU.

Keywords

International innovation cooperation; science, technology, and innovation; university–industry collaboration; innovation ecosystem; social network theory; institutional theory; Europe; China

1 Introduction

When the Horizon Europe programme called for effective ways of integrating research, innovation and their application (European Commission, 2020; Lamy et al., 2017), it also stressed prioritising international innovation cooperation and demanded more investment and wiser implementation strategies. The importance of international innovation cooperation has been further recognised by the EU and many other countries in the global response to the COVID-19 pandemic. However, compared to the proliferation of research on innovation on a national scale and innovation cooperation within the EU, the research on innovation cooperation between EU member states and third countries is lagging. The few studies that have reported the EU's innovation cooperation with third countries are mainly ad hoc (e.g. Cherry and Toit, 2018; Engel and Giorgia, 2016; Makkonen et al., 2018; Vullings et al., 2013), and the mechanisms underlying innovation cooperation remain unknown.

One of the most important but challenging cases is the EU's innovation cooperation with China. It is important because China is not only the EU's second-largest trade partner, but also has become a powerful player in science, technology and innovation (STI) (Basu et al., 2018). It is challenging not only due to the contrasting socio-economic systems of both sides (Mei et al., 2020) but also because of changing dynamics in EU–China relations. Although the EU and China have been committed to a comprehensive strategic partnership (European Commission, 2013), the European Commission's newly published *EU–China – A Strategic Outlook* points out that "the balance of challenges and opportunities presented by China has shifted" (European Commission, 2019); EU sees China as both a partner and a competitor in the economic domain.

Currently, the EU is developing a roadmap on science and technology cooperation with China that seeks to achieve two goals (Zubașcu, 2021). On the one hand, the EU wants intense cooperation with China, given the country's spectacular performance in science and technology development. On the other hand, the EU must impose stricter terms on collaboration to ensure that cooperation with China will not jeopardise the academic freedom and intellectual property rights of EU research organisations and companies. However, the two objectives are driven by different interests and logics. Thus, it is foreseeable that there will be more uncertainties and challenges to EU–China STI cooperation after the roadmap is launched. Therefore, deep empirical investigations and innovative theoretical thinking are urgently needed to provide helpful guidance for EU-China innovation cooperation in a new era.

To fully understand the present challenges in EU-China STI cooperation, one has to know the cooperation development in the past. The EU's and China's burgeoning interests in innovation cooperation were expedited by the signing of the *EU–China Innovation Cooperation Dialogue* in 2012, which complemented and ensured synergy with the *Agreement on Science and Technology Cooperation between the EU and China* in 1998. According to the *Joint Declaration on the EU–China Innovation Cooperation Dialogue*, 'the two Sides intend to discuss innovation strategies, jointly encourage and support cooperation on research and innovation, and to fully involve industry, universities and research institutes, to complement mutual strengths and deliver "win-win" results in the areas of human resources, skills, technology, research infrastructures, financing of innovation, exploitation of research findings, entrepreneurship and framework conditions for innovations' (European Commission, 2012, p. 2). The declaration indicates that innovation cooperation involves both industrial organisations and universities (and research institutes). The EU-China collaboration in both the industry and university sectors has been transforming in the past decade.

China's role in its industry collaboration with the EU is shifting from an important market and trade partner to an innovation partner (EU, 2016; European Union Chamber of Commerce in China, 2017). This is because China is not only the second-largest economy in the world but also has become the largest producer of scientific articles (Tollefson, 2018) and the world's second-largest research and development (R&D) spender (UNESCO, 2018). Indeed, many Europeans collaborate with Chinese partners in R&D in high-tech industries. For example, the Business Confidence Survey conducted by the European Union Chamber of Commerce in China (2021) reported that 'a mere 9% of European companies are considering moving any current or planned investment out of China, the lowest level on record' (p. 11). Despite top-

down support and bottom-up enthusiasm for EU–China innovation cooperation, it is surprising that few statistics on such cooperation are reported. Some rare studies providing such information include Wang et al. (2017), which reported 123,800 joint publications between China and 28 EU member states between 2000 and 2014, and Romagnuolo et al. (2021), which reported 140 EU–China collaboration patents in the field of personalised medicine.

EU–China university collaboration is facing increasing demands from society and stakeholders, as universities are being called on to shift the focus of their internationalisation strategies from international scholarship exchange to developing the EU–China partnership (Anonymised author's own reference). This echoes the notion of 'internationalisation in higher education for society' suggested by Brandenburg et al. (2020).

The transformations of EU–China cooperation in both higher education and industry will require synergy building, which is essential to building transnational innovation ecosystems (Cai et al., 2019). However, it is surprising how little interaction exists between the two areas of cooperation – higher education and industry – both in terms of policymaking and organisational practice. Moreover, synergy has not been addressed in research on EU–China innovation cooperation, as cooperation has been reported separately in universities (e.g. Fan et al., 2014) and industry (e.g. García-Herrero et al., 2017).

The research gap in EU–China innovation cooperation also reflects a paradox in innovation studies. On the one hand, there are widely shared perceptions of two tendencies: 1) innovation systems becoming globally interconnected (e.g. Liu et al., 2013; Necoechea-Mondragón et al., 2017) and 2) universities, especially their research, becoming increasingly vital to innovation systems (e.g. Brekke, 2020; Etzkowitz and Leydesdorff, 2000; Salter and Martin, 2001). On the other hand, studies on the roles of universities in innovation systems are mainly confined to national or regional contexts (Brekke, 2021), whereas the engagement of universities, especially in the form of international 'research collaboration' (Katz and Martin, 1997), in transnational innovation networks/systems has been surprisingly overlooked in the literature. Meanwhile, although international research cooperation has become an emerging domain of innovation studies, the extant literature on this topic has mainly focused on bibliometrics research and network analysis of research collaboration dynamics (Chen et al., 2019). Few studies have explored the influences of international research collaboration on international innovation cooperation in other sectors (e.g., industry).

Although no studies have directly tackled the research inquiry in this paper, there are a few that may shed some light on my research. Existing research on university and industry collaboration in international contexts focuses on two streams: 1) international corporations' collaboration with local universities in R&D activities (Liefner et al., 2019; Ma, 2019), and 2) universities' international branch campuses' roles in connecting firms from both home and host countries (Klerkx and Guimón, 2017). The first stream suggests that there is a potential for synergy building between universities and companies across geographical boundaries and identifies challenges in the synergy-building process related to trust and conflicting norms between the university and industry actors from different national contexts. It also implies that to resolve the challenges, additional actors must be involved. This led me to consider the advantage of synergy building between international university collaboration and international industry

collaboration, beyond the form of joint ventures between local universities and foreign firms, in developing international innovation cooperation. The present study is more thematically similar to the second research stream. In China, joint venture institutions between foreign and domestic universities represent the deepest level of international university collaboration (Ennew and Fujia, 2009; Lin, 2020). Current research mainly reports the educational aspects of these kinds of joint venture institutions; however, other forms of international university collaboration with a strong focus on research are expected to be discovered.

The lack of research on universities' roles in international innovation cooperation is probably due to the dearth of theoretical or conceptual tools needed to elucidate the phenomenon. According to Binz and Truffer (2017, p. 1284), 'while various analytical approaches have started to conceptualize the increasing importance of international linkages between regional and national innovation systems, a comprehensive and operable analytical framework for global innovation systems is still missing'. Although Binz and Truffer (2017) tried to develop a framework for understanding innovation dynamics in transnational contexts, their framework was decidedly industry-focused and did not take universities into account.

In the context of EU–China innovation cooperation, Cai et al. (2019) called for theoretical and methodological advancement of our understanding of universities' roles in the EU's international innovation cooperation. They also developed a useful concept—transnational university–industry co-innovation networks (TUICNs), which provides a conceptual framework for understanding the roles of international university collaboration in facilitating international industry collaboration aiming at value co-creation through innovation processes. Moreover, they argued that by developing TUICNs, many challenges in international industry collaboration, such as those caused by spatial distance between industrial partners from different countries, could be resolved. Nevertheless, Cai et al. (2019) mainly identified research gaps and proposed an agenda for future research rather than offering comprehensive solutions. Overall, the literature on EU–China cooperation is mostly ad hoc and not theory driven.

To bridge the aforementioned research gaps, this paper posed the following research question: *How does European and Chinese university collaboration help European companies turn collaboration challenges with Chinese counterparts into opportunities through developing TUICNs?* To answer this question, a new model of EU–China innovation cooperation was proposed. The research question was addressed using the following steps. First, an analytical framework (middle-level theory) for understanding the roles of international university collaboration in the development of TUICNs was constructed by integrating insights from social network theory and institutional theory. Second, the research method was introduced. Third, an empirical investigation was used to verify and enhance theory building. The study generated five propositions concerning the role of international university collaboration in the development of TUICNs in the EU–China context. Scholarly contributions and policy recommendations are discussed in the conclusion.

2 Analytical framework: The roles of international university collaboration in building TUICNs

The construction of the analytical framework in this paper can be seen in the process of multi-level theory interactions (Figure 1). Kezar (2006) distinguishes between four vertical levels of theory: meta-theory, grand theory, middle-level theory, and low-level theory. Kezar's key message is that there is a recursive relationship between higher- and lower-level theories: higher-level theories guide and influence theoretical development at the lower level, while lower-level theories build up to higher-level theories. In this study, a middle-level framework based on grand theories (i.e., social network theory and institutional theory) was used to guide the empirical analysis. The results of the data analysis were expected to generate propositions that would verify and strengthen the analytical framework. The innovativeness of the analytical framework lies in two of its features. First, it provides a novel approach to theorising about the mechanisms related to international university collaboration's roles in international industry collaboration by integrating social network theory and institution theory in the context of innovation ecosystems. Second, the theoretical elaboration leads to a new model of international innovation cooperation.

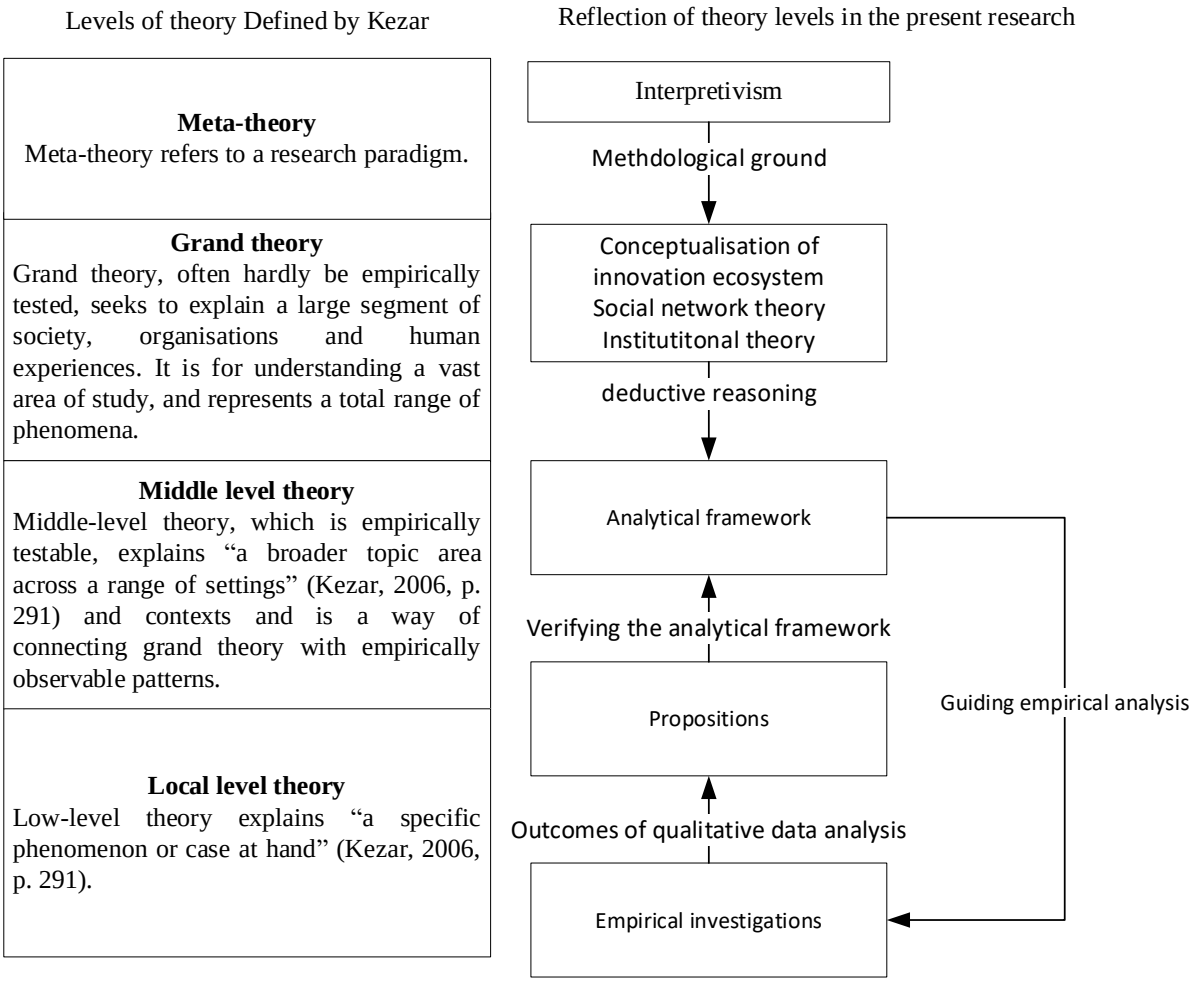


Figure 1. Levels of theory and reflection

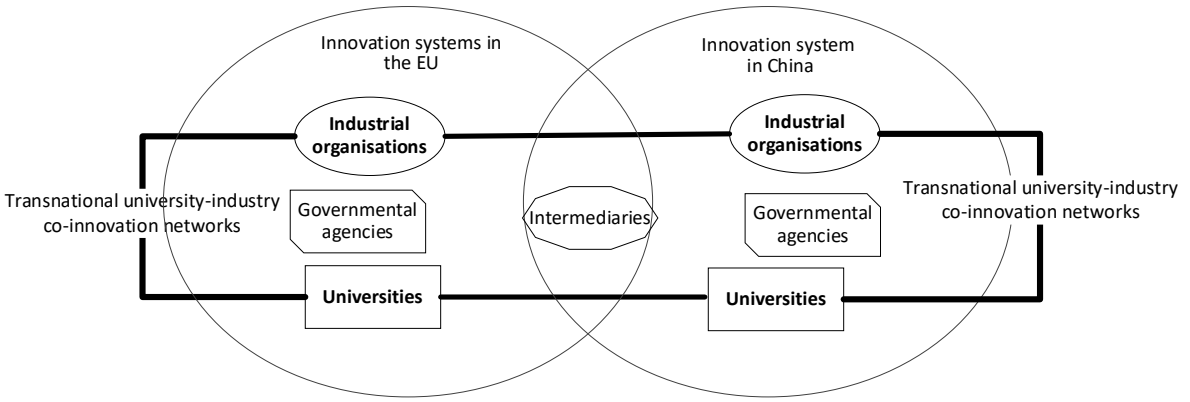
2.1 Definitions of major concepts

Before theory building, some central concepts, such as *international innovation cooperation* and *TUICNs*, need to be defined. All of these concepts are understood in the context of innovation ecosystems. Cai et al. (2020, p. 2) define *innovation ecosystems* as 'co-innovation networks, in which actors from organizations concerned with the functions of knowledge production, wealth creation and norm control interact with each other in forming co-evolution and interdependent relations (both direct or indirect) in cross-geographical contexts, and, through which new ideas and approaches from various internal and external sources are integrated into a platform to generate shared values for the sustainable transformation of the society'. One key implication of this definition is that innovation ecosystems tend to be transnational. The transnational or 'multi-locational' feature of innovation ecosystems was noted by Sotarauta et al. (2016) and Carayannis et al. (2018), who stressed that knowledge flows and innovation processes take place in multiple geographical locations. The transnational dimension of innovation networks has been widely reported in innovation research (Barnard and Chaminade, 2011; Lundvall et al., 2014; Necoechea-Mondragón et al., 2017; Pandey and Desai, 2017) and geography studies (e.g., Wixted, 2009). The networks are primarily interlinked through *international innovation cooperation* between actors from multiple sectors, such as higher education, industry, and government (Anonymised author's own reference).

In this paper, international innovation cooperation is used interchangeably with *international STI cooperation*. Cai et al. (2019) argued that the success of international STI cooperation is heavily based on synergy building among actors in *TUICNs*, which are characterised by 'collaboration, coordination, co-creation, convergence and complementar[it]y' (Saragih and Tan, 2018, p. 361) as a core feature of innovation ecosystems (Cai et al., 2020). The key components of these networks are international university collaboration and international industry collaboration, as well as the links between these two kinds of collaboration. While such networks help integrate new ideas and approaches and generate new and shared values in innovation processes, it is difficult to develop full-fledged TUICNs, as the links between international university collaboration and international industry collaboration are often unclear or hidden (Cai et al., 2019).

It should be noted that TUICNs are part of innovation ecosystems, in which other actors beyond the higher education and industry sectors are involved, which is illustrated in Figure 1 with EU–China transnational innovation ecosystems. Compared to national/regional contexts, the geographical, social, and institutional distances between actors in transnational innovation ecosystems, specifically TUICNs, are much larger. While geographical distance can hardly be altered, the dynamics of social and institutional distance, understood from the perspectives of social network theory and institutional theory, respectively, can be leveraged.

Next, an analytical framework concerning the roles of international university collaboration in facilitating the development of TUICNs was constructed. The framework focuses on how challenges associated with sparse networks and institutional distances, which characterise TUICNs, can be turned into opportunities through international university collaboration, as both social network theory and institutional theory suggest that challenges and opportunities are the two sides of the same coin of sparse networks and institutional distances.



Notes: Intermediaries refer to those consulting firms, non-governmental organisations, government-supported entities and projects that build links and support collaborations between innovation actors between the EU and China. Although the central argument of the paper is that European and Chinese universities in collaborative partnerships could also play the roles (but more than that roles) of intermediaries, in the figure universities are treated being distinct from the intermediaries.

Figure 1. TUICNs in transnational innovation ecosystems

2.2 The roles of international university collaboration in facilitating international industry partnership building: A social network theory perspective

2.2.1 Social network theory and its relevance to innovation cooperation

Social distance can be explained from the perspective of social network theory, especially insights regarding weak ties (Granovetter, 1973) and structural holes (Burt, 2000), both of which pay special attention to actors who bridge isolated networks and acknowledge their importance in innovation. Innovation requires a combination of both strong and weak ties (Abrahamson and Rosenkopf, 1997; Capaldo, 2007; Michelfelder and Kratzer, 2013), as 'weak ties aid exploration (the generation of new ideas), whereas strong ties aid exploitation (the implementation of new ideas)' (Barrie et al., 2019, p. 212). Accordingly, two types of network structures can be distinguished: dense networks and sparse networks, which are based on strong and weak ties, respectively (Kijkuit and Van Den Ende, 2007).

In dense networks, actors are fully connected via redundant channels of information flow and knowledge exchange. Such networks facilitate the establishment of a common language, mutual understanding and consensus formation, which can help coordinate collective actions by mobilising readily available trust and normatively constrained interests (Hemphälä and Magnusson, 2012). However, as they are characterised by close-knit structures, dense networks entail greater obstacles to generating new ideas and tend to exclude other actors beyond the initial densely linked groups (Obstfeld, 2005).

Sparse networks are rich in 'structural holes', which refer to discontinuities between groups of actors that have complementary sources of information (Burt, 2000). Actors bridging heterogeneous groups are likely to create new ways of thinking by selecting and synthesising

valuable ideas from different groups (Burt, 2004). Thus, actors whose networks span multiple nations enjoy strategic positions can play a crucial role as brokers to connect innovation networks across national borders.

2.2.2 Challenges and opportunities of sparse networks for international industry innovation cooperation

Based on the discussions above, it can be inferred that, compared to regional/national innovation (eco)systems, the networks between university and industry actors in transnational innovation (eco)systems are likely to be more sparsely connected in a geographical sense (i.e. larger spatial distances). Alguezaui and Filieri (2010) compared the pros and cons of sparse and dense networks in terms of innovation (as the outcome of collaboration in a network). While, in general, the benefits and risks of one network are the inverses of the other, the specific challenges and opportunities of sparse networks can be summarised in Table 1.

Table 1. Challenges and opportunities for cooperation in sparse networks for innovation

Challenges	Opportunities
Impeding the intense interactions that are necessary to gain a deep understanding of ideas in an innovation process	Source of unique knowledge and innovative ideas
Creating obstacles to action coordination (a lack of trust between actors in the networks)	Free flow of information, ideas and knowledge.
Inefficient implementation of innovative ideas	Efficient knowledge exploration and recombination

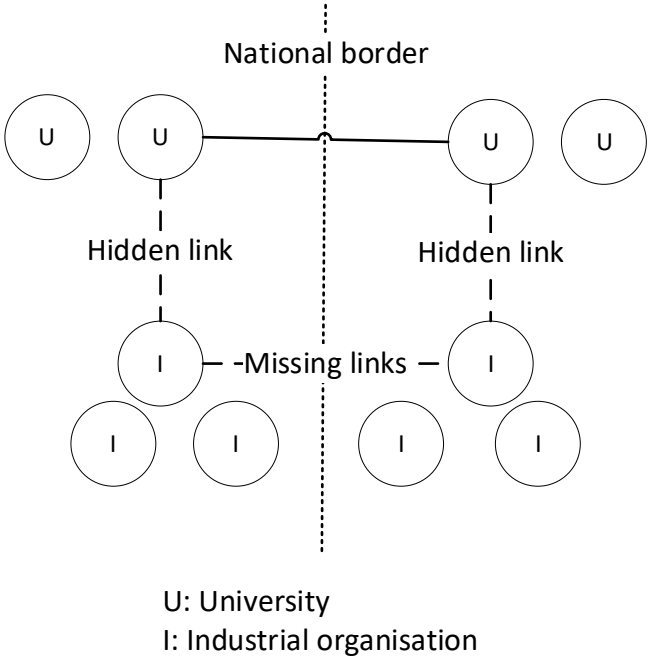
Source: Adapted from Alguezaui and Filieri (2010)

To fully take advantage of sparse networks while mitigating related challenges, Burt (2000) suggested bringing together both sparse networks (characterised by structural holes) and dense networks (characterised by network closure): 'while brokerage across structural holes seems to be the source of added value, closure can be beneficial to realizing the value buried in the structural holes' (p. 398). The key to such combined networks is the introduction of trust, which is typically seen in dense networks, into sparse networks. Trust helps enhance the efficacy of action coordination, since intense and effective interactions are enabled in trusting social contexts (Alguezaui and Filieri, 2010; Obstfeld, 2005). Trust among collaborative actors is also essential to creating shared visions (Bruce, 2002). Eboli (2015) found that sparse networks are more effective than dense networks at diffusing innovation when there is a shared vision of its benefit.

2.2.3 A social network theory perspective on the roles of international university collaboration in turning international industry collaboration challenges into opportunities

In international innovation cooperation, the industrial organisations from different countries can be seen as heterogeneous groups. Cai et al. (2019) suggested that two unfamiliar industrial organisations (with a missing link) from different countries could be connected for potential

collaboration by utilising their common connections to existing university collaboration, often at the individual level (see Figure 2). They further stressed that the ties between international university collaboration and international industry collaboration are often hidden because the links between them are unclear or the information revealing the links is obscured. Thus, by revealing such hidden ties, TUICNs can be created.



Source: Adapted from Cai et al. (2019)

Figure 2. TUICNs created through bridging hidden ties

International university cooperation plays two important roles in facilitating the development of TUICNs. One is to bridge match industrial organisations for international collaboration. As Reichert (2019) suggested in her report on the role of universities in innovation ecosystems for the European University Association (EUA), universities' contributions to innovation ecosystems extend from technology transfer to facilitating multi-actor co-creation. In other words, universities, as anchor organisations, can connect key actors in other sectors for value co-creation/co-innovation throughout the knowledge exchange process (Cai et al., 2020). However, a barrier to developing co-innovation networks is a lack of trust (Obstfeld, 2005), as actors from different countries can have diverse interests, perspectives and languages. Therefore, the other role of international university cooperation is to build trust between industry partners. Since international university collaboration involves relatively high levels of mutual understanding (Liu, 2017; Navracsics, 2017), it can enhance trust in international industry collaboration.

2.3 The roles of international university collaboration in leveraging institutional arbitrage in innovation cooperation: An institutional theory perspective

2.3.1 Institutional theory and its relevance to innovation cooperation

In institutional theory, a key concept for understanding different social norms across geographical locations is institutional distance, which refers to 'the difference … between the regulatory, cognitive, and normative institutions of . . . two countries' (Kostova and Zaheer, 1999, p. 71). Its antonym is 'institutional proximity' (Boschma, 2005). According to Boschma (2005), institutional proximity enables the establishment of a recognised socio-cultural, economic and political framework in which the actors are embedded. Thus, it reduces uncertainty and provides stable conditions for interactive learning and innovation. Boschma (2005) also noted that institutional proximity could harm innovation due to the problem of 'lock-in'. Therefore, institutional distance may offer solutions to lock-ins (Perkmann and Phillips, 2011).

Institutional distance can be well explained through the lens of institutional logic (Thornton et al., 2012), which is defined as 'a set of material practices and symbolic constructions' that constitute an institutional order's 'organizing principle' and that are 'available to organizations and individuals to elaborate' (Friedland and Alford, 1991, p. 248). A major argument in institutional logics theory is that multiple and contending logics provide the dynamics for potential change/innovation in both organisations and societies (Thornton et al., 2012).

2.3.2 Challenges and opportunities for international industry innovation cooperation characterised by institutional distance

While institutional distance between industrial actors in transnational contexts can entail challenges, especially in terms of reaching a consensus in innovation collaboration (Varga, 2006), it can also entail opportunities for innovation (Boschma, 2005; Thornton et al., 2012). Perkmann and Phillips (2011) used the concept of institutional arbitrage to explain how the institutional differences between the fields of academia and industry, subject to 'academic' and 'commercial' logics, can be leveraged in a national context. They refer to institutional arbitrage as the practice of arranging activities in different institutional settings to benefit from institutional differences. From an institutional logics perspective, institutional arbitrage is about how to turn the challenges brought about by the tensions inherent in complex institutional contexts into opportunities when organisation members can attempt to achieve valued organisational goals across sector boundaries. Consequently, Perkmann and Phillips (2011) discovered three types of benefits of institutional arbitrage and provided related enabling mechanisms as well as opportunities from these benefits (Table 2).

Table 2. Arbitrage benefits, enabling mechanisms and opportunities

Benefits	Mechanisms	Opportunities
Resources	Diverging organisational logics generate differences in resource munificence	Access to abundant resources in other fields
	Different valuation practices generate exchange opportunities	Access to undervalued resources available in another field

	Diverging interests reduce competition and opportunism	Exploit the effects of interests and expected behaviour
Legitimacy	Association with high-status actors in other fields	Borrow from another's reputation to enhance one's reputation without inducing competition
	Signalling effects via association with values and practices in other fields	Exploit symbolic association to emphasise the desirable aspects of one's activities
Ideas	Borrow elements from other logics	Deploy in other fields as a source of novelty
	Break out taken-for-granted procedures	

Source: Adapted from Perkmann and Phillips (2011)

2.3.3 An institutional theory perspective on the roles of international university collaboration in turning international industry collaboration challenges into opportunities

Innovation actors from different regimes are often subject to different institutional logics (Cai et al., 2019), shaped by both formal elements, such as laws and rules, and informal elements, such as values and routines (Boschma, 2005; Mattes, 2012). Although Perkmann and Phillips' (2011) study is based on a national context, the three mechanisms of institutional arbitrage identified in their study have generic explanatory power when it comes to people's strategic exploitation of institutional complexity, which also characterises international innovation cooperation. Therefore, these mechanisms and opportunities associated with institutional distance between universities and firms can also be used to explain the role of international university collaboration in leveraging opportunities for developing TUICNs.

2.4 Combining the roles for developing TUICNs

Structural holes and institutional distance between industrial organisations across national contexts can induce both challenges and opportunities. The roles of international university collaboration in turning international industry collaboration challenges into opportunities are summarised in Table 3 and fall into two categories: 1) bridging structural holes between industrial organisations on both sides through networking and trust building and 2) facilitating institutional arbitrage. By combining both roles, universities in international collaborative partnerships can serve as anchors for organisations in developing TUICNs, which may imply a new model of international innovation cooperation.

Roles from theoretical perspectives	**Specific roles**	**Combined roles**
Bridging structural holes	1. Connecting industrial partners from different countries	Contributes to building TUICNs
	2. Building trust between the industry partner organisations bridged through university collaboration	
Leveraging institutional arbitrage	3. Giving industrial actors access to new resources	
	4. Enhancing the reputations of international companies in their cooperation countries.	
	5. Breaking down taken-for-granted procedures	

Table 3. The roles of international university collaboration in building TUICNs

3 Research method and research data

Since synergy building between international university collaboration and international industry collaboration is underresearched, an exploratory qualitative research method was applied, which is suitable for gaining a deep understanding of an unknown phenomenon (Creswell, 2014). Nevertheless, it was not purely inductive research, which is typically seen in the grounded theory approach, using a 'systematic set of procedures to develop an inductively derived grounded theory about a phenomenon' (Strauss and Corbin, 1990, p. 24). Rather, the analysis in this study was guided by an analytical framework, as 'the use of theory … not only is an immense aid in defining the appropriate research design and data collection but also becomes the main vehicle for generalising the results of the … study' (Yin, 1994, p. 32).

The data sources in this study comprised in-depth interviews that I conducted with actors involved in EU–China innovation cooperation between autumn 2017 and spring 2018. One of the challenges of this research was to identify suitable interviewees, as there is little information concerning (best) practices of synergy building between international university collaboration and international industry collaboration in the EU–China context. In addition to using my own networks, my strategy for seeking relevant practices and interviewees was to participate in events involving pioneer actors in EU–China innovation cooperation. Three criteria were applied when selecting interviewees: 1) they had to be engaged in EU–China innovation cooperation, representing either a university, industry, or government; 2) their engagement in EU–China innovation cooperation had to involve multiple EU member states; and 3) the industrial fields of innovation cooperation were priorities for both sides.

The majority of the interviewees included in the study were participants of three events in which I also took part. Two of these events were the matchmaking tours of an EU-funded project for supporting and connecting European research, innovation, and business organisations to China, which took place in October 2017 and May 2018, respectively. The third event was the Sino-Finnish Forum on Universities as Platforms for Scientific Innovation and Technology Transfer, held in November 2017. Some interviewees from these events introduced me to additional relevant informants. The remaining interviewees were either my own contacts or were introduced to me by them.

Although more than 20 interviews were conducted, only 18 were included in the analysis (Table 4), as the remaining interviewees mainly talked about collaboration within an industry or university rather than interactions between them. All the interviews were conducted face to face using semi-structured interview questions. The main discussions in the interviews were about the interviewees' engagement in the intersections between international university collaboration and international industry collaboration, as well as their perspectives on the roles of the former in facilitating the latter. While the interview questions were principally guided by the analytical framework, the interviewees were expected to report all related matters from their perspectives. Except for one interview (with I2), all of them were audio recorded. The interviews covered university collaboration and industry collaboration between China and several EU member states, including Belgium, Germany, Finland, the Netherlands, and Portugal.

Table 4. Description of the interviewees

Interviewee ID	Duration of interview	Sector	Type of organisation	position	Location of workplace	Gender	Main work activities
I1	90 min	Industry	A European consulting firm in China	CEO	China	Male	Providing consulting services to European companies doing business in China
I2	20 min	Government	An EU office in China	Section head	China	Male	Supporting EU–China cooperation in STI
I3	43 min	Industry	A Finnish firm for promoting business development	CEO	Finland	Male	Facilitating business cooperation with China in technology fields
I4	42 min	University	A research centre jointly run by a Chinese university and a European university	Coordinator	China	Female	Coordinating a joint centre established by a Chinese university and a European university
I5	74 min	University	A collaboratively run university college between a Chinese university and a European university	Coordinator	China	Female	Coordinating a joint college supported by the Chinese government and the government of an EU member state
I6	52 min	Government	An EU platform for supporting European business development in China	Director	China	Male	Supporting the development of EU small- and medium-sized enterprises (SMEs) in China
I7	53 min	Government	A European country's business promotion office in China	Director	China	Male	Supporting one EU member state's business development in China
I8	33 min	Government	An EU office in China	Country representative	China	Female	Supporting EU research cooperation in China
I9	23 min	Industry	A European consulting company, Board member		Portugal	Female	Coordinating an EU–China STI cooperation project
I10	89 min	Industry	A company owned by a European university	CEO	Finland	Male	Doing business with China for technology transfer
I11	34 min	University	A European university	Head of China Office	Belgium	Female	Coordinating a European university's collaboration with Chinese universities and stakeholders

I12	34 min	University	A European university	Coordinator of China Office	Belgium	Male	Coordinating a European university's collaboration with Chinese universities and stakeholders
I13	30 min	Industry	A European country's project for promoting business development in China	Director	Finland	Male	Coordinating an information communication and technology (ICT) network between China and a European member state
I14	32 min	Industry	China branch of a European consulting firm	Director	China	Male	Coordinating an EU–China STI cooperation project
I15	49 min	University	A European university	Vice President	Portugal	Male	Occupying a leadership position at a European university
I16	39 min	University	A European university	Head of China Office	The Netherland	Male	Managing technology transfer to China at a European university
I17	96 mins	University	A Chinese university	Programme Coordinator	China	Female	Coordinating international collaboration of an MBA programme at a Chinese university
I18	31 min	NGO	A Chinese platform for supporting European business development in China	Director	China	Female	Providing services for European companies landing in China

All the interviews were transcribed and then coded using NVivo (qualitative data analysis software). The coding concerning the role of international university collaboration in building TUICNs was mainly guided by the analytical framework when identifying the roles of international university collaboration. When identifying the challenges and opportunities associated with EU–China industry collaboration, an open coding strategy was initially applied and then the challenges were categorised according to the perspectives of social networks and institutional distances.

4 The roles of universities in EU–China innovation cooperation

Guided by the analytical framework (Table 3), I empirically investigated how international university collaboration contributes to the development of TUICNs, particularly in turning international industry collaboration challenges into opportunities in the context of EU–China innovation cooperation. In the empirical study, I identified four examples of best practices regarding the role of EU–China university collaboration in turning EU–China industry cooperation challenges into opportunities, based on the analysis of the 18 interviews with participants representing seven organisations. Table 5 describes the major characteristics of the examples. It also summarises the roles of international university collaboration in facilitating international industry collaboration produced by the empirical data analysis that is presented in detail below. Although only five interviewees were associated with the four examples, information from the other interviewees was also used in the analysis.

Table 5. Examples of best practices

Descriptions of the best practices examples that reflect the roles of EU–China university collaboration in turning EU–China industry cooperation challenges into opportunities					Findings from the analysis following the analytical framework (Table 3)				
Example ID and key interviewees (Interviewee IDs) engaged in the cooperation example	EU–China university collaboration	The focus and coordination of the university collaboration	EU–China industry collaboration	Links between university collaboration and industry collaboration	Roles of international university collaboration in facilitating international industry collaboration				
					1	2	3	4	5
Example 1 I10	The European university EU1 (in Country A), a global leader in the scientific field SF1, had an eight-year research collaboration with the Chinese university CU1. EU1 is among the top 100 in the Academic Ranking of World Universities. CU1 is a 985 university (One of the top research universities in China).	• Research collaboration in a specific field • Coordinated by individual researchers	The European company EC1, a spin-off EU1 in the field of SF1, collaborated with several Chinese companies, mainly to capitalise on the knowledge produced by EU1 in the field of SF1.	EC1 was connected with its Chinese partner companies through CU1.	++	++	++	+	o
Example 2 I5	The governments of both China and Country B (an EU member state) jointly established the Sino-B	• Research and teaching collaboration involving	Several companies from Country B, which sponsored the Sino-B College, e.g. through	The partnership between companies from Country B and China was largely	+	+	++	++	o

	College located at the Chinese university CU2 20 years ago. The college had a close collaboration with several top universities from Country B.	multiple disciplines • Coordinated by CU2	setting up chair professor positions after the name of the companies, had business collaboration with Chinese companies.	facilitated by the staff and alumni of Sino-B College.					
Example 3 I11 and I12	The European University EU3 in Country C established the China Platform to coordinate the university's broad networking with China 15 years ago. EU3 is among the top 100 universities in the ARWU ranking. CU2 is a 985 university.	• Services facilitating EU3's and the local government's cooperation with China • Coordinated by the International Office of EU3	Local companies linked with EU3 in Country C collaborated with Chinese companies.	The professors from EU3 helped the companies in Country C connect with Chinese companies that had links with the Chinese universities with which the professors had research collaboration.	++	+	o	o	o
Example 4 I13	Several key universities in the field of ICT from Country A and China, together with some research institutes and companies, formed the Sino-A ICT Alliance 10 years ago, a project supported by the governments of China and Country D.	• R&D collaboration in the ICT field • Coordinated by the project coordinator, a university professor from Country A.	The collaborative companies from both China and Country A were members of the Sino-A ICT Alliance.	The collaborative relations between the companies from China and Country A were established through the alliance, but they also had close ties with the universities of both sides of the alliance.	o	o	o	o	++

Notes: ++ = Strongly evidenced by the examples; + = Evidenced by the examples; o = Not mentioned by interviewees. See interviewee IDs in Table 4.

4.1 Matching industrial partners from both the EU and China

4.1.1 Challenges to be tackled

The role of international university cooperation in connecting industrial organisations from both the EU and China helps to address a particular challenge: while many European technology companies have been attracted by envisioned opportunities in China, they knew little about the situation there and thus had difficulties finding the most suitable partners. I6 emphasised how understanding the Chinese market was the basis for the success of European companies moving into China. I13 shared a similar observation:

> *The Chinese market is ultra-competitive. Today's situation is that Chinese technology companies, including Chinese start-ups, have developed very rapidly, and one thing that these companies from [Country A] should do is try to understand what the current state of the Chinese environment is – in order not to make false assumptions.*

I3 suggested that one way to avoid making false assumptions is to collaborate with local partners in China. When European companies seek Chinese business partners for collaboration, it is important to build a partnership through someone who knows both sides (I4). In practice, the most links between European and Chinese companies were consulting firms (I1), supporting agencies (I6, I18) and other foreign entities in China (I7). Several interviewees (I1, I6, I7, I9) noted that when European companies, especially SMEs, sought Chinese counterparts for cooperation, they normally went directly to the industry sector and collaborated with the first Chinese companies that came along.

However, these partners were seldom the most suitable ones. Indeed, it was difficult for Europeans to check the credibility of their potential Chinese partners (I9). I7 warned European businesspeople: 'If they [Chinese companies] are too eager, too desperate to do business [with you], it could be because they don't have enough business here otherwise'. He further stressed that the success of European companies in the Chinese market depends on how they select their Chinese partners and build trust with them.

4.1.2 Opportunities generated by international university collaboration

Collaborating universities from the EU and China could help connect suitable industrial partners from both sides. In Example 1, the research group at EU1 intended to capitalise on their cutting-edge knowledge in the scientific field of SF1 in China. In so doing, EU1 needed to collaborate not only with its Chinese partner university CU1 but also with the Chinese companies connected to CU1. However, it was practically difficult for EU1 to work directly with Chinese companies. As I10 explained:

> *For Chinese companies, it is quite difficult to collaborate with universities, because it is very difficult for the Chinese local government and risk investors to understand the role of a university.... In China, academies have quite a bad reputation of being ineffective. Therefore, Chinese companies*

sometimes think that academic activities are like a 'money pit;' it is good to fund a university, but it doesn't produce money for society. (I10)

Therefore, EU1 established a spin-off company, EC1, to facilitate its business collaboration with Chinese companies. In this example, a TUICN was formed through collaborative relations between EU1 and CU1.

Similarly, in Example 3, it was mentioned that a civic engineering professor played an important role in linking companies from China and Country C through his research collaboration with a leading Chinese university in the field (I11). In Example 2, although the Sino-B College at CU2 was not directly involved in matching Chinese and European companies, many European companies' (from Country B) connections with their Chinese counterparts were facilitated by the faculty members and alumni of the college (I5).

The interview analysis discussed above led to Proposition 1: *European companies can connect with suitable Chinese industrial partners through EU–China university collaboration*.

4.2 Building trust between industry partner organisations

4.2.1 Challenges to be tackled

The role of international university collaboration in building trust between industry partners helps deal with the challenges of trust building, which is crucial for partnerships between European and Chinese companies. Building trust is costly. The relationship between collaboration and trust is also a chicken-and-egg issue: good collaboration is based on trust, but trust can only be built through long-term collaboration. As said by I7:

Building trust is a key issue, but it takes time. It is not built over one trip to China for two weeks or even for a few months.... We even realised that some companies had spent two or three years in China before getting their first deal.

4.2.2 Opportunities generated by international university collaboration

Compared to a business partnership established independently or through business brokers, one bridged through EU–Chinese university collaboration can build trust more quickly. In Example 1, since EC1 (EU1's spin-off) and Chinese companies were connected via EU1 and CU1, which had a long-term research collaboration, they could effectively do business together right away without trust issues. This is in stark contrast to the experiences of many European companies working with Chinese partners that have to be patient while investing resources and time into trust building. When EC1 expanded its business in China, it developed 'a policy of only working with Chinese companies that have close ties with [EU1]'s collaborating Chinese universities' (I10).

Nevertheless, it should be noted that building trust between European and Chinese universities also expensive and time consuming. I10 described EU1's collaboration with CU1:

> *The most important thing in China is that first, you have to be present a lot. You have to show the Chinese partner that you are interested in them. And the Chinese university gets lots of requests for collaboration from abroad.... If we want to be successful, we have to be present. So that's why, in the first few years, we went there with our own funding, visited them, and thus we were able to establish a joint laboratory with our fund at CU1 to start the first measurement activities. And then when we got good results, slowly CU1 was able to use those results [produced by the laboratory] to ask for funding from China.... Now the funding for the joint laboratory didn't have to come from our side anymore.*

Companies from the EU and China would save both time and money if they could strategically utilise existing trust between European and Chinese universities to strengthen their collaboration. This led to Proposition 2: *European and Chinese companies connected through EU–China university collaboration can build mutual trust more quickly.*

4.3 Giving industrial actors access to new resources

4.3.1 Challenges to be tackled

The role of international university collaboration for contributing new resources to international industry collaboration helps tackle the challenge for companies in the high-tech industry: the realisation of innovative business ideas is often constrained by available financial resources. I6 noted that, as most European companies in China are SMEs, a major challenge is insufficient resources, e.g., in terms of investment capital. For this reason, 'they [the SMEs] are normally [having] a bit shorter [life cycle in China] because they don't have enough resources to stay here that long enough to try out the market' (I6). Similar views were shared by I3, who emphasised that, compared to business operations in Europe, more resources are required for European SMEs in China. He further explained this with an example:

> *If there is an official negotiation where some kind of ministers or high-level political decision-makers are with the Chinese partners, they can say that they have the resources and [to make the deal] we [companies on the European side] will provide two million euros [as a co-investment]. [The challenges are], first of all, they don't have the two million euros, and even if they did, they don't have permission to make commitments on this negotiation table. (I3)*

4.3.2 Opportunities generated by international university collaboration

All four examples, particularly the first two, imply three kinds of resources from which EU–China industry collaboration can benefit by networking with EU–China university cooperation, namely 1) additional R&D resources, 2) employment investment savings, and (3) efficient use of funding for corporate image building. The first two are evidenced

in Example 1. When the university and industry actors collaborated, they were entitled to apply for R&D projects that promoted university and industry collaboration. Moreover, EU1's spin-off company, EC1, had financial savings from reduced costs by hiring full-time researchers. For example, when EC1 needed to analyse business-related data in China, the company simply made a contract with EU1. As explained by I10:

> *Human resource costs are quite high for a new and small technology company.... If you have your own employees, then the costs are even higher, especially when you don't know if the business concept works or not. In the way we are operating, we can keep the cost low.*

The third kind of resource is reflected in Example 2. At Sino-B College, there were several chair professorship positions named after the companies (from Country B). These companies were motivated to sponsor the positions to promote the company's image and train the talent needed by the companies. From a financial perspective, this was a very cost-effective way of investing in corporate image building. As explained by I5:

> *In fact, [Country B]'s companies can enjoy tax benefits for donating money to the Sino-B College. However, tax reduction or exemption might not be their major consideration. Donating funds to education not only reduces the tax but also enhances their corporate image. The companies can benefit from both.*

The interview analysis discussed above led to Proposition 3: *EU–China university collaborations can provide industry partners with resources that are rarely available in the industry sector.*

4.4 Enhancing the reputation of European companies in China

4.4.1 Challenges to be tackled

The role of international university collaboration for enhancing the reputation of European companies in China is against the challenge faced by many European SMEs in China in promoting its visibility and reputation in the Chinese market. As I6 pointed out, many European SMEs come to China with good technology and prefer to focus on technology development, hoping that Chinese experts can help market their products in China. Indeed, for an 'unknow' European company, the 'Chinese market is very competitive; [if you want to be successful] you either have a very good brand that is already known in the market, or you have some way to make it known very quickly' (I6). Making one product visible in the Chinese market is an all-consuming task, and 'that's why people go for [Chinese partnership] because they know a Chinese partner can help them accelerate [the process]' (I6). While leaving the marketing to their Chinese partners can be a valid strategy, European SMEs must 'view risks [of doing business in China], especially with regard to things like intellectual property rights …And [another risk is related to] how [their Chinese partners] want to be involved in the market themselves [a

motivation issue] and how they have proximity to the Chinese customer [a capacity issue]' (I6).

4.4.2 Opportunities generated by international university collaboration

Being associated with prestigious universities greatly enhances European companies' reputations. An extreme case is Example 1, in which EC1, as a spin-off of EU1, immediately gained a good reputation in China because of EU1's position as a global leader in the scientific field SF1 and its long-time research collaboration with CU1. In Example 2, companies from Country B tried to enhance their reputations by sponsoring Sino-B College. As explained by I5:

> *Enterprises' investment in education can enhance the corporate image; this is one aspect. Another aspect is that [Sino-B College] holds an advisory committee meeting every year. Senior government officials and business representatives from China and [Country B] attend it. Such a meeting is equivalent to a club. Therefore, many companies are very willing to join. If you want to join such a high-level club, you need to sponsor the [Sino-B College] ... Nowadays SMEs are more eager to invest in the college, e.g., by setting up chair professor positions.*

The interview analysis discussed above led to Proposition 4: *European companies, especially SMEs, can quickly establish their reputation in China if they are associated with prestigious European and Chinese universities via collaborative partnerships*.

4.5 Breaking down taken-for-granted procedures

4.5.1 Challenges to be tackled

The role of international university collaboration in breaking down taking-for-granted procedures helps resolve the challenge faced by European companies in protecting their intellectual property (IP). Some challenges were explained by I13 — the Coordinator of the Sino-A ICT Alliance in Example 4:

> *First of all, Chinese companies patent a lot. So, one thing that a Western company needs to be aware of – they might actually violate a Chinese company's patent when going to China, which is a big risk. But the bigger risk still is that your technology becomes very much exposed when you go to China, and China is still fairly enough a copy culture.... IP protection schemes are more and more enforced in China. But naturally, there is a delay while the Chinese government wants to of course learn – as any other government – about these new technologies.*

When European technology companies want to introduce their products in the Chinese market, the challenges mentioned above are unavoidable, though having an excellent Chinese partner can help to moderate such challenges (I13).

4.5.2 Opportunities generated by international university collaboration

To overcome these challenges, I13 presented a new business model they learned about from the practices in Example 4, in which universities and companies from both China and Country A formed a consortium, similar to the concept of TUICNs. The main ideas of the new business model were described by I13 as follows:

> So, one good approach applying now in the medical or healthcare innovation areas is that we go science first, where w*e have universities as platforms*. Science by nature is more open, you create new results, and you share it openly with the scientific community. And then it's up to the companies to create competitive products or unique IP based on the science. In this way, we can go to a new *scientific* field, so that China can add tremendous value to the global knowledge, e.g., on what analysis techniques there are, or what kinds of interventions work for people with diabetes or cardiovascular disease in the field of precision healthcare. And China is actually the world-leading country in some techniques in the field.... *So, I would not always worry about the IP and copying, though we have to be aware of it, as it is a real risk. But when you understand that you can create new value that you could not create alone, it helps you find new solutions for a much larger market and a larger audience. And this could be a big competitive edge for Chinese and Europeans working together.... So, the one thing you should always ask is: 'What can we achieve together?'*

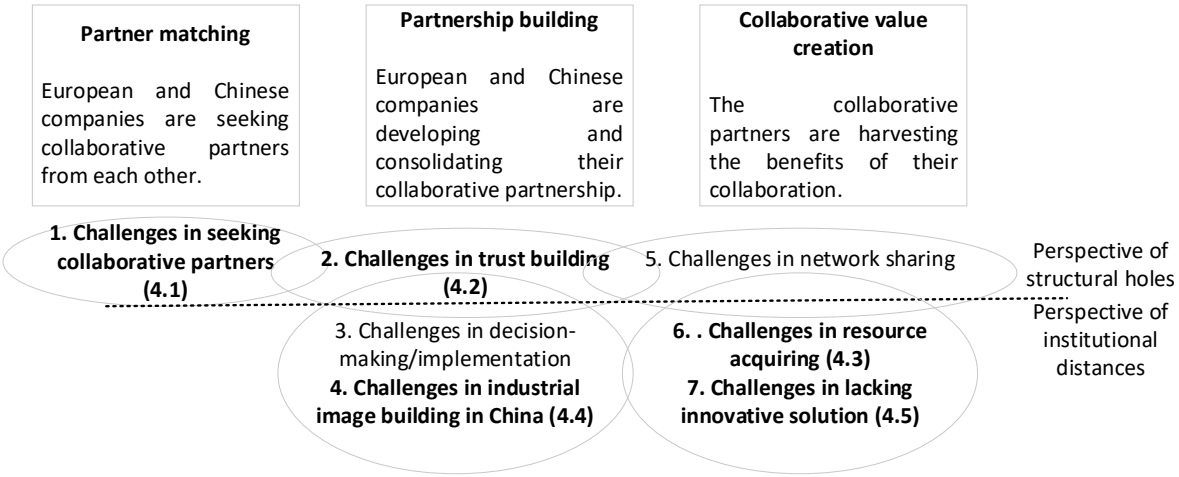
The interview analysis discussed above led to Proposition 5: *European companies are likely to develop novel business operations in China when working closely with European and Chinese universities.*

5 Towards a new model of international (EU-China) innovation cooperation

When all the roles mentioned above are combined, significant outcomes can be expected, such as resolving challenges in international industry collaboration, leveraging opportunities through building TUICNs, and envisioning a new model of EU–China innovation cooperation. These are explained below, respectively.

5.1 Resolving challenges

The challenges associated with EU–China innovation cooperation that were identified through the interview analyses are illustrated in Figure 3.



Note: The challenges written in bold font refer to those challenges in EU-China industry collaboration that are mitigated or even turning into opportunities through the roles played by international university collaboration. The challenges written in normal font refer to those challenges in EU-China industry collaboration that are not evidentially tackled by international university collaboration.

Figure 3. EU–China innovation cooperation challenges in the industry sector

By playing all the roles mentioned above, international university collaboration can help resolve most challenges in international industry collaboration. However, the interview data do not show clear evidence that both challenges in decision-making/implementation and the challenges in network sharing in China can be directly resolved through international university collaboration. Both challenges were identified through the interview analysis, as explained below.

Challenges related to decision-making/implementation are caused by normative differences between both sides, as illustrated by I3:

> *Basically, the Chinese party and our party [from Country A] come to negotiations from totally different starting points. On the Chinese side, they have already done some kind of homework regarding what can be decided before coming to a negotiation. Because of our tradition, unfortunately, we spent lots of time in different negotiations, and it takes much more time to get any kind of decision.*

When it comes to implementation, the interviewee added, 'that is the advantage on the European side because there is less possibility of change when something has been decided.' In China, there were still uncertainties during implementation, even after the issue had been decided. Replacing key individuals in an organisation can significantly impact implementation.

Challenges related to network building are due to the unique way that people connect in China, which often hinders European companies from effectively utilising their Chinese partners' networks. Compared to Europeans, who are generally fine with sharing their

networks with friends, Chinese people have a strong sense of ownership of their networks, as explained by I7:

> *If someone wants to get connected to some people in [Country A] in my network, I will just share the contact details and then let them talk to each other.... If I ask my Chinese friend to introduce me to someone in his network, he would be in that meeting when I meet the introduced person.*

5.2 The leadership and anchor roles of international university collaboration in building TUICNs

Besides mitigating challenges, international university collaboration also helps take advantage of more opportunities in international industry collaboration, which were described above. Most importantly, TUICNs form when all the roles of international university collaboration, as mentioned above, are combined. This distinguishes the bridging role of international university collaboration from that of other (traditional) brokers or intermediaries, which only help connect industry actors for collaboration without joining them in the innovation processes. Of course, international university collaboration could also benefit from international industry collaboration; however, this was not the focus of this study.

Examples 1 and 3 clearly demonstrate the leadership role of universities (or their role as anchor organisations) in developing TUICNs in the following two aspects: 1) university professors as visionaries and 2) universities as anchor organisations. In Example 1, one professor from EU1 was considered by I10 as a visionary because of his role in developing strategic partnerships with Chinese universities and, most importantly, due to his wisdom in utilising the university collaboration to facilitate business collaboration. In I10's words:

> *Already eight years ago, we made our investment [in building the research collaboration with CU1] for the future, and now I like the outcome of the investment.... [Our current operating model is] to make sure that our vision for the following years until 2030 will become successful because we have a long-term vision in our department.... I would not say EU1 has a long-term vision to work in China, but Professor K, the head of our group, does.*

Example 3 shows that the China Platform at EU3 played a central role in developing broad cooperation between Country C and China, involving actors from the industry and government sectors. The China Platform was not simply for coordinating EU3's collaboration with Chinese universities; it also developed a strategic partnership with the local government and chamber of commerce to support their collaboration with China. Together with the local government, they set up a liaison office in China. EU3 indeed became an anchor organisation by developing collaboration networks across the university, industry, and government sectors of both sides (I11, I12).

Due to the chosen research focus and limited data, the present paper cannot fully explore TUICNs. For example, the interview analysis points out several important issues that are beyond the scope of this study.

First, building TUICNs not only requires the participation of university and industry actors across countries, but it also depends on environmental conditions and the support of other actors, which are beyond the scope of the study. For example, the interest fit between the two sides on innovation cooperation from political, science and market perspectives (I2, I6, I13, I16) can be a conditional factor affecting the development of TUICNs. The stories told by I7, I13 and I16 reflect the important role of government agencies (concerning partnership development, trust building and resource allocation) in developing TUICNs.

Second, as the study primarily focused on the European perspective when examining EU–China innovation collaboration, a full understanding of the nature of TUICNs requires investigations from both the European and the Chinese perspectives. Nevertheless, this study's findings show that the knowledge flow is mainly from the EU to China and that the resource flow is primarily from China to the EU.

Third, regardless of the significant potential of international university collaboration in building TUICNs, some interviewees (I11 and I12) noted that there is still much room for improvement in terms of realising this potential and, to this end, learning from best practices and bold experimentation are needed.

5.3 Envisioning a new model of EU–China innovation cooperation

Building TUICNs can lead to a new model of international innovation cooperation. Traditional international innovation cooperation consists of two parallel collaborations in the sectors of university (research institutes) and industry, where the connections between organisational actors in the two sectors are mainly in domestic contexts and through knowledge exchange (Cai et al., 2019). The new model is characterised by synergy building between international university (research) collaboration and international industry collaboration through bridging structural holes and leveraging institutional arbitrage. The traditional and new models of international innovation cooperation are illustrated in Figure 4.

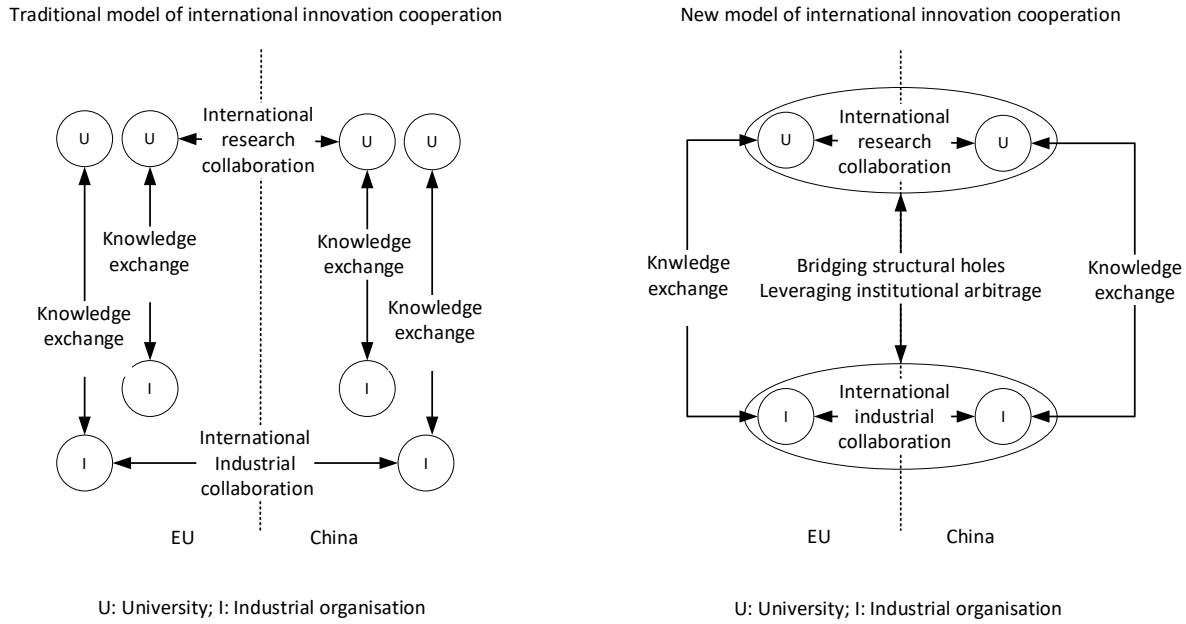


Figure 4. Traditional and new models of international innovation cooperation

It should be noted that when elucidating the new model, this paper focused on the roles of international university collaboration in building TUICNs in its theory building and the European perspective in its empirical investigations. The study also implies other important issues related to the model. First, international industry collaboration can also facilitate international university collaboration. Second, the cooperation must be mutually beneficial to partners from the EU and China, since reciprocal cooperation is the foundation for sustainable international cooperation (Guimón and Narula, 2020). Third, to best facilitate the development of TUICNs, governments (in collaboration) are expected to provide supportive policies and impose normative changes. Theoretical elaboration on these ideas is needed to further enhance the new model. However, as these are beyond the scope of this paper, they must be further developed in future research.

6 Conclusion

Although the EU has attached great importance to STI cooperation with third countries and has made huge investments in it, our theoretical and empirical understanding of the nature of the EU's international STI cooperation, especially the dynamic interactions between international collaboration in university and industry sectors, is surprisingly limited. As a response to the research challenge, this paper investigated the role of international university collaboration in developing TUICNs by taking the EU–China innovation cooperation as an example. By conceptualising the phenomenon and integrating the insights of social network theory and institutional theory, an analytical framework focusing on the five roles of international university collaboration in turning

international industry collaboration challenges into opportunities was constructed. The basic theoretical assumption is that, while sparse networks and institutional distance can be both challenges and opportunities in international industry collaboration for innovation, international university collaboration can help largely turn the challenges into opportunities. In the process, universities can play leadership and anchor roles. The framework was applied in an analysis of interviews with 18 actors engaged in EU–China innovation cooperation. This qualitative analysis led to five tentative propositions that verified and concretised the five roles suggested in the analytical framework. Based on the findings, a new EU–China innovation cooperation model was proposed, paving the way for further strengthening and expanding the analytical framework.

It should be mentioned that in the four examples of best practices selected to demonstrate the role of EU–China university collaboration for facilitating EU–China industry collaboration, what they had in common was that the university collaborations were all engaged in applied research fields. This is understandable, as companies are more interested in technologies or research results that can be immediately put into production and markets. Moreover, the universities from both the EU and China sides in the four examples were all prestigious research universities. It can be inferred that prestigious universities may be better at performing their roles, e.g., in terms of trust building and image enhancement; however, more research is needed to verify this.

Besides offering both theoretical and empirical explanations of the role of international university collaboration in facilitating EU–China innovation cooperation, this paper makes two other contributions to the extant literature. First, it addresses a paradox in innovation studies. While there are many discussions in the literature on both the vital role of universities in national/regional innovation systems and the tendency of innovation systems to become globally interconnected, little research attention has been given to the engagement of universities, particularly international university collaboration, in transnational innovation (eco)systems. As a pioneering study, this paper integrates two disconnected research areas, namely international university collaboration and international industry collaboration. Second, it not only justifies the call by Brandenburg et al. (2020) for linking internationalisation in higher education to global societal engagement with empirical evidence but also provides initial theoretical accounts of the roles of international university collaboration in developing TUICNs as a core of transnational innovation ecosystems.

This study has three limitations. First, as it investigated an area with little information on where the most relevant cases and actors exist, it was impossible to identify representative cases beforehand, which would have been methodologically preferable, as this would have maximised the generalisability of the research findings. In the study, I found most of the interviewees through active participation in various events on EU–China STI cooperation, and representative examples (best practices) were only identified during the data analysis stage. For this reason, the number of interviewees in each example was limited. While the information provided by the interviewees confirms the theoretical

assumptions developed in the paper, each example can be further investigated in the future with more informants representing different aspects of the cooperation. Second, the patterns concerning the interactions between cooperation in university and industry sectors in the EU–China context cannot be fully explored by a qualitative investigation due to the complex nature and large scale of the interactions. Thus, statistical analyses and even big data analyses, as suggested by Cai et al. (2019), are required to further probe the field. Third, although the findings of the empirical investigation in the EU–China context may shed light on the EU's STI cooperation with third countries, the degree of universality is limited by the context. The propositions yielded by the study need to be further tested in other settings.

The findings of the study lead to the following recommendations for policymakers, universities, and companies in the EU. First, there should be more dialogue between two areas of policymaking: EU–China higher education cooperation and EU–China industry cooperation. European universities have already developed profound collaborations with Chinese universities through huge investments in recent decades that has mainly concentrated on research, education and mobility. Take into account European universities' collaboration with China would help to develop strategies for industry collaboration on both sides, which would multiply profits from the same investment. Second, European universities and companies, especially those in the same countries or regions, should strengthen their communications/interactions not only to promote local economic development but also to develop joint China strategies/actions if they both have an interest in cooperation with China. Third, to realise the potential of EU–China university collaboration in EU–China innovation cooperation, innovative services provided by governmental agencies or through publicly funded projects should be envisioned. For instance, in the EU, agencies that facilitate international university collaborations could include the engagement of university collaboration to link European companies and industrial actors in third countries as their service scope. In China, services provided by regional governments to attract foreign companies could be expanded to attract both companies and universities from a target country.

At the time of writing this paper, EU–China relations are challenged by the current COVID-19 pandemic and the rapidly changing relationship between the world's major powers. In the eyes of the EU, China has shifted from being primarily a comprehensive strategic partner to a system rival (European Commission, 2019). The EU Chamber of Commerce in China (2020) wrote that 'China-based European companies find themselves navigating in the dark' (p. 1). However, as China will remain an important country for knowledge production and as a market for Europe, EU–China innovation cooperation will not cease. Therefore, both the EU and China are seeking new ways of innovation collaboration. The model proposed in this paper may be worthy of consideration. For instance, in the current situation, it is essential to utilise university collaboration, which is less affected by geopolitics (Lee and Haupt, 2020), to help international industry collaboration maximise rewards while minimising risks. Hopefully, this paper serves as

an icebreaking effort on the role of international university collaboration in EU–China innovation cooperation and will encourage more researchers to explore this research area.

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Hybridization in the Business Model Context: Opportunities and Potentials for Science and Industry

Fabienne Schützner[1], Kevin Reuther[1], Christian-Andreas Schumann[1]
[1] University of Applied Science, Zwickau Germany

Abstract
The consideration of hybridization in a business context to address 21st-century challenges is receiving increasing attention in the academic debate (Vaceková et al., 2015). Hybridization as a one-dimensional mechanism creates a gradation between two absolute states and can be used in different areas of business as an instrument of abstraction and control. In connection, the literature focuses on the management of internal tensions and competing value-added targets, and the resulting negative consequences for companies predominantly (Davies & Doherty, 2019; Reuter, 2021). While the role of hybridization in entrepreneurship is increasingly getting attention in various contexts, the application and study of this phenomenon in the field of business models gained awareness in the academic debate just recently (Reuter, 2021). Therefore, there is no clear overview of the scope, nature, and main topics of the research field so far. Based on this, there is a high need for new research on this topic to sharpen the theoretical understanding of hybridization in the business model domain and to derive concrete recommendations for action in the industry on this basis. Accordingly, the aim of the research is, to investigate the application of hybridization in the business model literature, identify research gaps, and derive potential for future investigations.

Keywords
Entrepreneurship, Hybrid Organizations, Hybrid Business Model, Hybrid Value Creation, Sustainability, Hybridization.

1 Research Methodology

In this paper, we use a systematic literature review, following Tranfield et. al (2003), starting with the research question and selection of databases, followed by the definition of search terms, and finally concluded with a schematic filtering and selection process to identify the occurring literature Adjacent, a conceptual modeling approach according to Jaakkola (2020) is used to describe connections and contradictions between the considered dimensions of hybridization using a framework. The location of the hybridization within the companies is a determinant of the framework. The selection of the application areas is subject to a systematic selection procedure. Based on the contents as well as the absolute states of the examination, we localize the hybridization within the company. Accordingly, the discussion section focuses on the application and location of hybridism in companies. To conclude, impulses for science, industry, and future research are pointed out.

2 Results

Based on the reviewed literature, we develop a conceptual framework to describe and compare hybridization in the entrepreneurial dimensions based on three identified application dimensions: hybrid organizations, hybrid business models, and hybrid value creation. Connections and contradictions between the dimensions are elaborated and put into context. The research findings indicate that fuzzy conceptual distinctions between the hybridization-phenomena cause a diversity of application and research, which is not limited to the business model level of the companies. This implies a highly heterogeneous field of research that investigates hybridization in different entrepreneurial dimensions. The differentiation between the organizational level, the business model level, and the value creation level offers a new approach to structuring the research field. Moreover, hybridism turns out to be fundamental to social entrepreneurship (Doherty et al., 2014). In addition, the transfer of hybridization to other entrepreneurial dimensions offers opportunities for future research in social and sustainability entrepreneurship.

3 Discussion

The analysis of the literature reveals that only single authors deal with a multidimensional classification of hybridization-phenomena, which generates possibilities for new multidimensional hybridization spectra. It is also evident that solving societal and environmental problems are the focus of a larger portion of the literature. The role and influence of innovation in various fields are increasingly incorporated and studied in this context. In general, the studies in the research field are predominantly application-oriented, which means that individual phenomena, such as sustainable hybrid and classic hybrid business models, are only considered in specific contexts. As a result, there are few generalized studies on these business models themselves. The fuzzy delineation of the identified dimensions also offers potential for interface studies, for example between the implementation of hybrid forms of value creation and the optimal realignment of the existing business model. This may lead to innovative and precise research designs that can be used to fill existing research gaps and gaps in understanding of individual hybridization-phenomena.

4 Conclusions

The results of this work contribute to the specification and fragmentation of the research field of hybridization in the business model domain. Future research can build on the results of this work. Thus, extending and validating the identified entrepreneurial dimensions through complementary literature, other databases, or empirical studies can validate the classification of hybridization in a business context and concretize identified research gaps. The fragmentation creates new starting points for further investigations of

individual hybridization-phenomena. Through targeted data collection and analysis, newly identified phenomena such as sustainable hybrid business models can be identified in terms of their construction and implementation, representing an opportunity for new research. The fulfillment of sustainability goals through a systematic hybridization of two business models can be structured and conceptualized in terms of sustainable hybrid business model archetypes. These or similar research approaches can open alternative paths for the integration of sustainability and profit management in science and industry.

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Indicators for Knowledge Transfer: Mapping, Measuring, and Managing

Swen Günther[1], Silvia L. Popova[1], Thomas Falter[2]

[1] HTW Dresden, University of Applied Sciences, Faculty of Business Administration
[2] OTH Regensburg, University of Applied Sciences, Faculty of Business Administration

Abstract
The university research landscape in Germany has been repeatedly criticised for the fact that the excellent scientific output is insufficiently transferred to economically usable applications. In order to uncover the weaknesses of knowledge and technology transfer, an effective measurement and indicator system is required. For this reason, research activities in this area have increased recently, especially funded by state institutions such as the Federal Ministry of Education and Research (BMBF).

Relevant publications and studies contain a large number of proposals for key figures and indicators. These are intended to provide as comprehensive a picture of the transfer process as possible. The point of view of the transfer provider, i.e. the university, is often in the foreground. Until the present moment, transfer recipients such as economy and society have received less attention. The analysis of these subsystems was part of the cross-university research project 'Transfer_i: Transfer Indicators'.

In this paper we describe an effective approach for mapping, measuring, and managing of transfer processes by using key performance indicators (KPI). Therefore, a systematic analysis and description of the (research-based) transfer processes at the subsystem level were carried out. The main causal relationships in knowledge and technology transfer were determined for each sub-system, e.g. state, research, economy, society. The results were aggregated on the basis of a multidimensional model.

Keywords
Transfer_i, Transfer Indicator, Transfer Process, Research-based Transfer, Innovation System

1 Introduction

1.1 Research Projects on Transfer Indicators in Germany

The transfer of knowledge from universities and non-university research institutions has been researched for many years. In addition to the derivation of scientific explanatory models, the focus is primarily on measuring the transfer process using suitable indicators. On the one hand, this involves increasing transparency in the transfer process and providing efficient control instruments. On the other hand, the individual performance of the institutions should be improved – more in the interest of own continuous development and increasing transfer than competitiveness with other researchers and institutions. In order to include all facets of knowledge and technology transfer in an innovation system, holistic indicator models are required based on the underlying transfer processes.

In the past, various indicator models have been developed to evaluate the transfer performance of universities and (non-university) research institutions. Relevant models and assessment approaches come from the Centre for Higher Education (CHE) and the Wissenschaftsrat (2016). The current research projects and initiatives in Germany include the BMBF-funded research project 'Transfer_i', the joint project 'Transferbarometer' of the Stifterverband and the working group for indicators of the 'TransferAllianz e.V.' (Figure 1). The HTW Dresden is actively involved in two of the three projects and has developed indicator sets at the subsystem level together with partner institutions.

Project	**Transfer_i**	**Transferbarometer**	**TransferAllianz**
Goal	Determination of indicator sets for controlling of research-based transfer from infvention to actual innovations on the market	Development of transfer indicators for self-control, profile building, further development and communication/ marketing	Development of a field-tested, standardized set of indicators for (comparable) measurement of activities in the context of KTT
Phases	Conception, Analysis, Synthesis	Development, Validation, Consolidation	Continuously, No phases
Focus	Subsystems of Innovation System	Universities/ Research Institutes	Universities/ Research Institutes
Research	Literature Review Expert Survey Case Studies	Expert Workshops Experimental Tests	Expert Group (Arbeitskreis)
Model	3D-Transfer Model - Systems, Objects, Processes -	Transferbarometer - Enablers, Results -	IOOI Approach - Input, Output, Impact -
Partners	HTW Dresden, HTWK Leipzig, OTH Regensburg, DHI Köln	RWTH Aachen, HTW Dresden, Universität Düsseldorf, Universität Kassel + 6 Helmholtz-Zentren	Arbeitskreis Indikatorik of TransferAllianz
Leader	HTW Dresden	Stifterverband	TransferAllianz
Sponsor	BMBF/ DLR	Stiftung Mercator	TransferAllianz e.V.
Duration	2.5 Years (2019-2022)	1.5 Years (2020-2021)	Ongoing, since 2020
References	Günther at al. (2021) SRHE/ UIIN/ furueSAX	Frank et al. (2019) Lehmann-Brauns et al. (2021)	White Paper (2021)
Homepage	www.transferforschung.de	www.stifterverband.org	www.transferallianz.de

Fig. 1: Research Projects on Transfer Indicators in Germany (Selection)

1.2 Transfer_i: A Joint BMBF Research Project (2019-22)

As part of the comprehensive Transfer_i research project, a set of indicators was developed for the objectification of research performance, research-based transfer and its implementation on the market, e.g. innovations. A key starting point is the description of the causal relationships in the innovation system, taking into account the subsystems involved, such as the economy and society. A total of three German universities are involved in the joint research project, lasting over 3 years, and funded by the BMBF. The HTW Dresden and HTWK Leipzig belong to the Saxon transfer network 'Saxony[5]' while

the OTH Regensburg is a constituent member of the East Bavarian transfer network TRIO (Link: https://wihofo.bmbfcluster.de/de/transfer-i-2698.php).

The description of the transfer activities is oriented on the relevant indicator models in the subject area. The 'Innovationsindikator' from BDI/Fraunhofer et al. (2015), for example, is based on a model-based indicator system made up of individual indicators. These in turn are divided into the following so-called 'subsystems' within the innovation system: state, science, education, economy, and society. A similar model approach with five subsystems can be found in the 'Quintuple Helix Model' by Carayannis et al. (2017). The basis for the derivation of transfer indicators in the Transfer_i project is a 3-dimensional model (Figure 2), which considers several criticisms of approaches to modelling knowledge and technology transfer (Bormann/Günther, 2020).

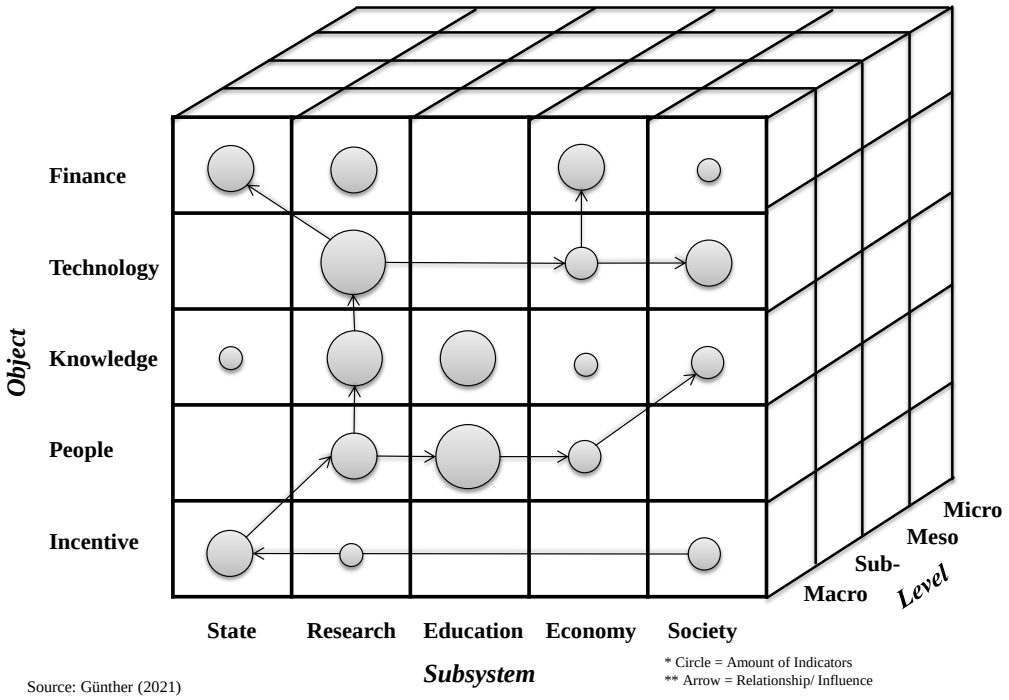

Fig. 2: 3D-Transfer Model for Systematic Classification of Indicators

2 Theoretical Basis

2.1 Process-oriented Modelling of Knowledge Transfer

The basic models for describing the transfer process can be subdivided into system-, process- and actor-based models (Cummings/Teng, 2003). From an overall perspective, all models aim to describe transfer structures and processes by using essential components or elements on one or more levels of abstraction. This is often leads to a (significant) reduction in complexity and a focus on certain areas of action that are considered 'particularly important' for the transfer, e.g. input-output relations (Perkmann, 2011). Depending on the research focus, the innovation system as a whole or only parts of it are

taken into account. Hence, neither 'knowledge', 'technology', 'technology transfer', nor 'knowledge transfer' is free of controversial issues (Bozemann, 2000).

With regard to the systematic analysis and improvement of the transfer in and out of organisations, the process-oriented approach is particularly suitable (Günther et al., 2021). Based on the continuous improvement process (CIP), there is a systemic view of knowledge and technology transfer in the form of empirically traceable cause-effect relationships across the entire innovation process. Based on new, research-based knowledge, the related transfer from the transfer provider to the transfer recipient is traced in a process-oriented manner. Generated transfer objects and necessary transfer resources, formats and channels are explicitly included in the analysis.

The identification and selection of indicators depends on the purpose of the indicators. It ranges from the annual collection of key figures for documentation/external presentation to the systematic uncovering of strengths and weaknesses (benchmarking), to the operational planning and control of transfer activities at different levels by the researchers, the research laboratories, the universities, as well as the regional research and innovation eco-systems. In all three cases – also following the logic of CIP in quality management – the internal/external transfer recipients (customers) should be the starting point for the derivation of transfer-related key figures. It is difficult to identify process-influencing factors and actors due to the complexity of the transfer process. Thus, it requires a more detailed analysis of the subsystems involved.

2.2 Scientific-inductive Approach for Deriving Indicators

The research process is subdivided – at a high level – into the three phases of conception, analysis, and synthesis. The analysis phase contains three empirical investigation methods: As part of a systematic literature search, indicators from relevant sources were collected and evaluated to create a representative database. The findings are related to more recent publications and studies, both in the university and non-university areas. Two-thirds of the research covered German-language sources, followed by English-language sources, primarily from the British university system. The raw data set, adjusted for synonyms and duplicate entries, comprises >700 indicators (Beckmann et al., 2021).

In order to condense and prioritise these indicators, expert interviews were then conducted on the basis of a semi-structured questionnaire. A total of >60 experts were interviewed in the period 2020/21. Analogous to the defined subsystems, the interviewees included representatives of public institutions, higher education and research as well as business and (civil) society. While three out of four experts stated that transfer processes – especially in the form of knowledge – take place very regularly, more than two thirds of those surveyed also confirmed the use of indicators or monitoring to track the processes. In the course of the expert interviews, >200 additional indicators were identified.

In the third and final step, detailed analyses were carried out at the subsystem level. In the subsystem ‘Economy’, this affected the more detailed examination of the DAX 30

corporations (Günther/Janitz, 2021). They represent the most important companies in Germany from an economic point of view and usually have extensive relationships with universities and research institutions. A high level of transparency in this area is therefore likely. The companies´ current annual reports served as the basis for the empirical study. A total of (only) 13 key figures or indicators for knowledge and technology transfer could be determined. In conclusion, economic organisations have very few indicators in this area compared with other organisations, e.g., universities and research institutes, but in comparison to the other subsystems they are consequently applied.

3 Empirical Findings

3.1 Use of Transfer Processes and Indicators in Organisations

The development of indicator sets in the Transfer_i project is largely based on the experts-survey conducted in relevant subsystems in 2020/21. Among other things, the (exploratory) interest in the survey was on the ‘organisational anchoring’ of transfer processes and indicators. A comparison of the individual subsystems shows a very heterogeneous picture (Figure 3). All interviewed persons in the subsystem ‘Research’ (100%) and 83% of those in the subsystem ‘State’ confirm that ‘transfer processes’ are part of the overall organisational goals. In contrast, the approval ratings of the respondents in the subsystems ‘Society’ (53%) and ‘Economy’ (33%) are relatively low, which is not surprising given the general strategy of these organisations, e.g., companies.

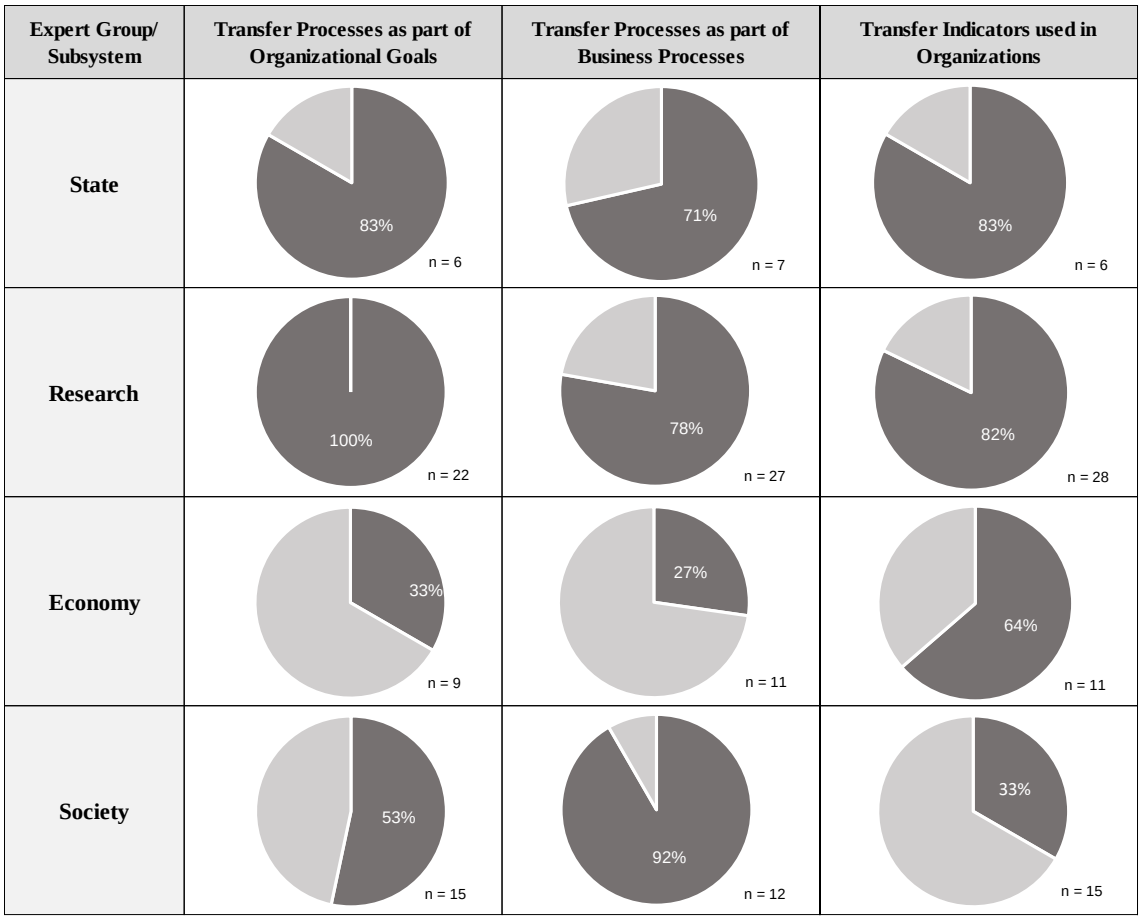

Fig. 3: Organisational Importance of Transfer Processes and Indicators

A similar result emerges with regard to the consideration of transfer processes in the core or business processes of the organisation. The approval ratings of the representatives of 'State' (71%) and 'Research' (78%) are relatively high, while 'Economy' (27%) is significantly lower. Less than 1/3 of company representatives (27%) see knowledge and technology transfer processes as part of core processes in their organisation. At the same time, 2/3 of the respondents (64%) confirm that they use transfer indicators. Higher scores are only achieved in the organisations of the subsystems 'State' (83%) and 'Research' (82%); (civil) society organisations use comparatively few indicators (33%), but regard transfer processes as part of their core processes (92%).[1]

3.2 Categories of used Indicators for Transfer Measurement

In a further step, the authors investigated in which areas of knowledge and technology transfer the experts consider transfer processes and transfer indicators to be (particularly) relevant. For this purpose, the answers of the respondents were grouped inductively,

[1] In the Transfer_i project, 10 interviews were conducted with professors from university, who are mainly involved in administration and teaching activities, e.g., vice-rectorate. The professors were interviewed as representatives of the subsystem 'Education". Since a different questionnaire design was used, the survey results are not included in this evaluation.

mainly according to the underlying transfer object, e.g., ‘event’. Accordingly, a total of 22 groups or categories could be identified for ‘transfer indicators’ (Figure 4). The results are sorted by relative (overall) frequency and show – on a second analysis level – the sub-results by subsystems. The numerical values in the diagram indicate the average number of responses per interview (normalised). Transfer indicators are mentioned most frequently in connection with ‘Projects’ (54 of 289 responses or 0.89 responses per interviewee (61)), followed by ‘Events’ (0.64) and ‘Ext. Funding’ (0.48).

When comparing the subsystem-related results, it is noticeable that, on the one hand, the ranking is very heterogeneous across all transfer indicator categories. On the other hand, there is relatively large heterogeneity in the results of individual groups in a cross-subsystem comparison. For example, ‘Projects’ are very important for organisations of the subsystems ‘State’ and ‘Research’ while they are of relatively less importance for ‘Economy’ and ‘Society’. The same applies to ‘Ext. Funding’ and ‘Publications’. In contrast, ‘events’ are very important for the experts of the ‘Society’ subsystem, while for the ‘Economy’ – less surprisingly – the measurement of ‘Economic Success’ counts above all. Compared with this, the ‘Social Impact’ and ‘Qualitative KPI’ are of (overall) little importance, which was quite unexpected for the authors.

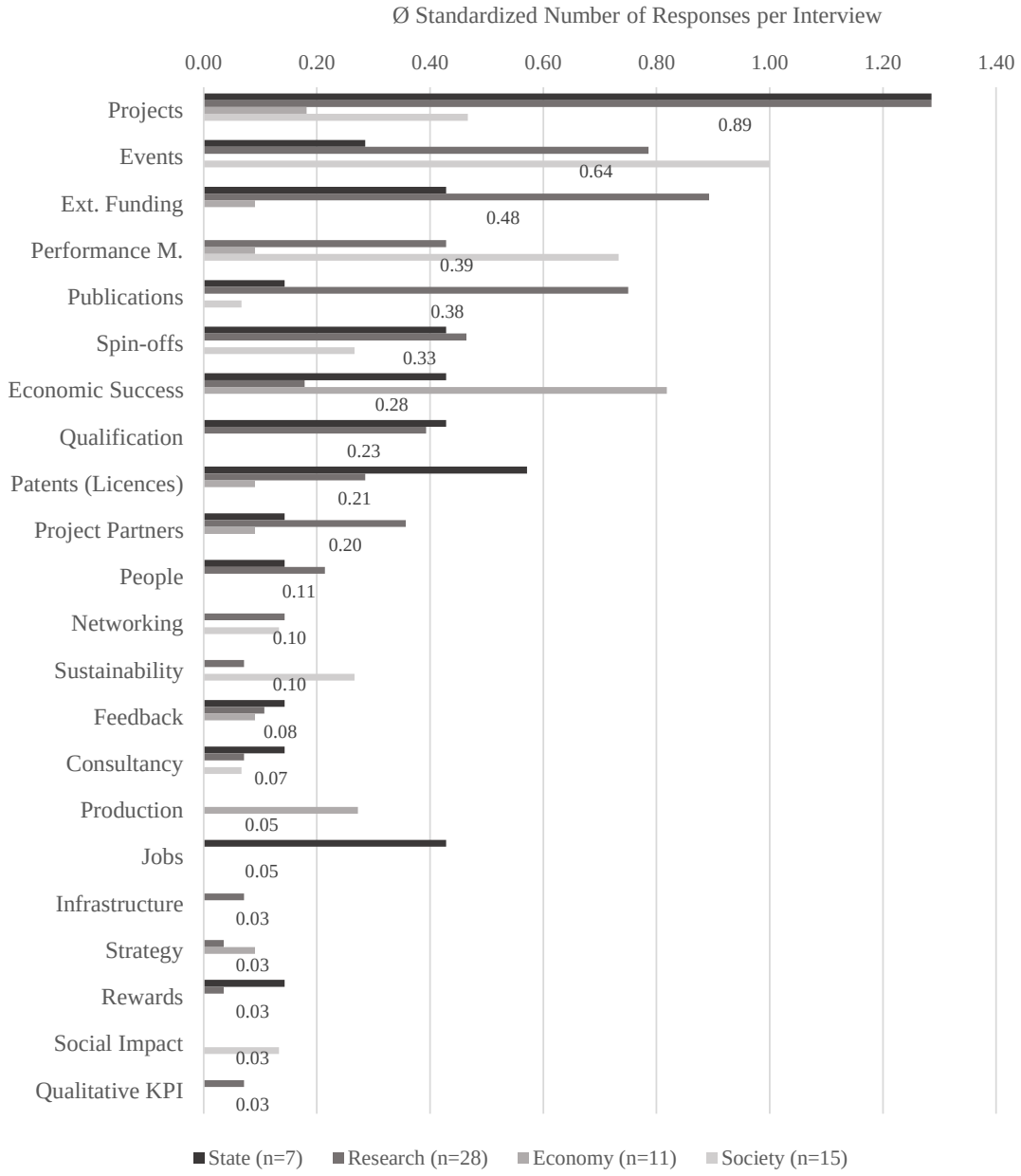

Fig. 4: Clustering of Transfer Indicators by Interview Results

4 Tools in Practice

4.1 Strategy Map for the Management of Transfer Processes

In most of the existing indicator models, the institutions involved in the innovation process are considered separately. This makes cross-organisational measurement and control of transfer more difficult. The assumption of a direct cause-effect relationship, i.e., more research leads to more innovation, cannot be confirmed (Fuhrland et al., 2017). To overcome this obstacle, the use of proven management tools such as a ‘Strategy Map’ with differentiated goals is recommended (Günther et al., 2021). In this context, Kaplan

& Norton´s (2004) Strategy Map serves as the model-theoretical basis. It is the 'roadmap' for the planning and control of transfer processes and includes the (normative) representation of causal chains across different target levels, e.g., transfer objectives. The tool can be used for certain areas, e.g. R&D, as well as for the entire organisation.

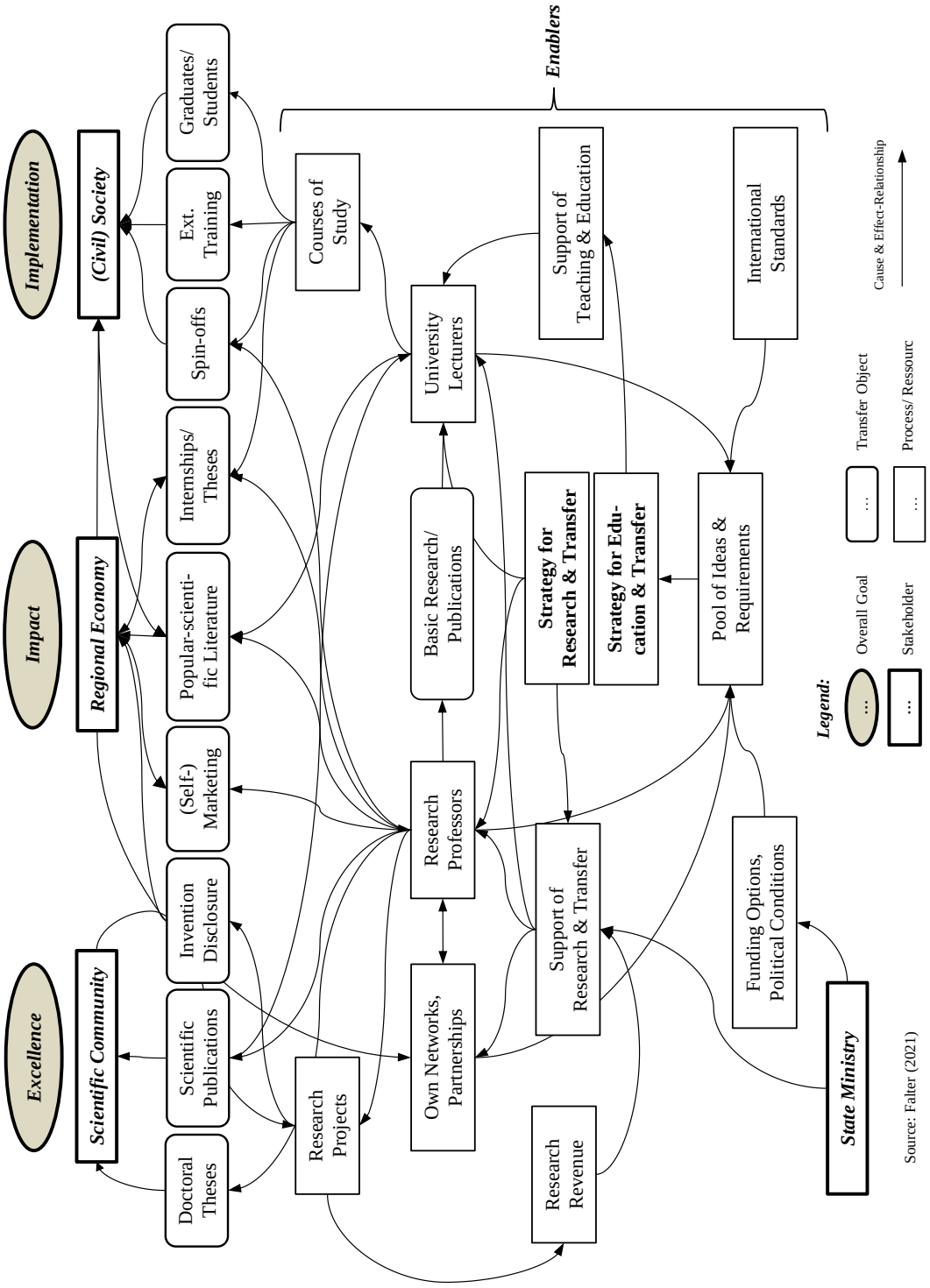

Fig. 5: Strategy Map for University´s Transfer Management (Example)

By depicting important cause-effect relationships, the strategy map allows performance measurement, process control and continuous learning for the entire organisation. The starting point for the derivation and networking of ‘success factors for transfer’ are the organisations or stakeholders of the adjacent subsystems, e.g. ‘Economy’ and ‘Society’. Figure 5 shows an example of the strategy map developed by the project partner OTH Regensburg. With regard to indicators, the model is based – at the highest level – on the award criteria of public funding conditions of the European Commission (2019): Excellence, Impact, and Implementation. Recursive transfer relationships are also taken into account, e.g., ‘Scientific Community’ influences ‘Networks, Partnerships’.

On the level below, the transfer objects, such as doctoral theses, are shown, which depend on the underlying processes and resources. They are called ‘Enablers’ in compliance with the EFQM-Model (Günther et al., 2021).[2] As soon as one of the enablers shown does not (or cannot) make its contribution to the subsystem, the creation and transfer of the transfer objects is at risk. The authors therefore recommend introducing indicators at the different levels of the strategy map, not with the primary goal of performance measurement, but for self-control and for continuous learning and improvement.

4.2 Scorecard for the Measurement of Key Performance Indicators

In order to use the strategy map for operational planning and control of transfer processes, a scorecard with KPIs has to be created in a further step. Only this enables the measurement of the current state of knowledge and technology transfer and the initiation of improvement processes. In the long-term, the (assumed) cause-and-effect relationships can be verified empirically via early assessment. Relationships between single KPI´s that cannot be statistically verified are eliminated and new, previously undiscovered ones can be added. In doing so, the success factors for transfer are refined in an iterative process and the forecast quality of the strategy map will increase continuously.

The indicators for evaluating transfer performance are usually derived from the target agreements between the university and the state, e.g., Bavarian target agreement 2019-2022 (Innovation Alliance 4.0). In these agreements the higher education policy topics are fixed, e.g., the role and function of higher education institutions as socially active and responsible entities. Furthermore, important indicators from other subsystems, e.g. economy, can serve as guidelines for universities and should be the basis for planning and improving of transfer processes. This facilitates the transition from an ‘inside-out’ to an ‘outside-in’ perspective. Figure 6 shows the transfer indicators (KPI) of the DAX 30 companies, which were researched in the Transfer_i project.

[2] The EFQM model of the European Foundation for Quality Management has been a reference standard for designing an ‘excellent” quality management system since 1988. The basic model from 2013 is based on a criteria-based analysis and evaluation of the quality of existing organisational structures and the results achieved with them. The conceptual foundations for an adapted EFQM model in the area of knowledge and technology transfer were also researched in the Transfer_i project.

Object	Indicator (KPI)	Type	Target	Actual
Finance	• Expenditures for R&D • R&D-Rate • Revenue of Products from Alliances	Quantitative	-- € -- % -- €	
Technology	• Number of Patents • Value of Patents • Intangible Assets	Quantitative	-- # -- € -- €	
Knowledge	• Research Alliances with Universities • Participation on Conferences	Qualitative		
People	• Recruitments (All) • Recruitments from Universities • Dual Study Courses & Theses	Quantitative	-- # -- # -- #	
Incentive	• Social Networks & Digital Platforms • Hubs/ Networks for Transfer	Qualitative		

Fig. 6: Scorecard with KPI´s of the DAX 30 Companies (Example)

5 Outlook

5.1 Improvement Challenges at Universities

The type and form of the professional design of the transfer structures and processes largely depends on the prevailing transfer culture of the organisation (obligation/support) and the transfer competence of the people (ability/willingness). If both are not fully established, the outcome of cross-organisational transfer activities will be limited. At universities, in particular, there is often a great need for change in the design and control of knowledge transfer structures (Scherm, 2021). Nevertheless, the willingness to change the status quo varies significantly among the institutions. The introduction of a scorecard with transfer indicators can be a first step to raise the level of importance, according to the common motto: ‘What cannot be measured, cannot be improved.’

However, for the two areas of application, research and education, the scientific-theoretical foundations of KTT should be adapted. Based on this, the need for change in universities´ transfer structures and processes can be analysed and systematically optimised. For this purpose, integrated model approaches must be developed which allow a KPI-based control of transfer activities, taking into account relevant cause-and-effect relationships. Besides the implementation of tools, a high level of motivation and acceptance among the people involved, e.g., professors, has to be ensured. This leads us to the main challenge facing the world today. In many organisations, there is no consensus on what ‘Transfer’ really is, what it does and does not include, and how it should be controlled.

5.2 Further Research Requirements

Research on transfer is an emerging field of science, which is becoming more and more important. The development of new products or services involves many organisations from different subsystems. The understanding of these transfer processes is crucial to achieve a strong, resilient, and successful innovation management. However, many explanatory models do only insufficiently depict the complexity, causal connections, multidimensionality, and multidirectionality of the transfer activities (Bozeman, 2000). Additionally, there is no precise definition of the root word ‘transfer’ and its many combinatorial follow-up terms, e.g., transfer process, transfer object, transfer format. In order to develop well-founded and reliable model approaches, first the terms and definitions, used by the different stakeholders involved, have to be aligned and standardised.

Similarly, all parties of the innovation system should be taken into account in order to development an effective measurement system. Today, organisations involved in the innovation process are usually considered separately from one another. This makes cross-organisational measurement and controlling of KTT difficult. The assumption of a direct cause-and-effect relationship, i.e., more research leads to more innovation, cannot be confirmed in many cases. As outlined above, knowledge and technology transfer is a complex process between different partners of different subsystems with different goals. Therefore, a set of indicators is required for controlling the entire process from invention to innovation. Unfortunately, this often leads to a trade-off between the number of indicators required and the effort (time, cost) needed to collect the data.

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Multi-skill technology gateways: The core of successful innovation partnerships

Alex Vakaloudis[1], Brian Cahill[1]

[1] Munster Technological University, Nimbus Research Centre, Cork, Ireland

Abstract

Our work focuses on autonomous entities inside academic institutions that may be supported by state seed funding to manage innovative industrial partnerships. Technology Gateways (term used in the Irish Innovation Ecosystem) engage with industrial and community partners to progress innovative concepts ideally up to high (6-7) Technology Readiness Levels (TRL) and handover services or products close to commercialisation. Achieving high TRLs is an important metric for the success of an academic-industrial partnership. Without it, early research results are not adequately exploited, the engagement is neither sustainable nor fruitful for either party as it yields no clear benefits to the industrial partner. We argue that to ensure holistic, sustainable support in innovative partnerships from the academic side, a technology gateway needs to encompass multiple capabilities to be able to autonomously deliver end-to-end products or services to a high TRL. We define a core skill set (Insiders) that must be present for the Technology Gateway to be able to produce digital platforms, IoT devices and physical apparatuses. Working under Agile processes, Insiders collaborate with partnering companies as well as the underlying research community to receive and materialise insights that lie outside their expertise. The result is the formation of an entity inside academia that tackles knowledge transfer through shared processes and skills and results in adequately supporting sustainable innovation partnerships.

Keywords

University-Industry Innovation partnership, core academic innovative skills, high technology readiness level

1 Introduction

Technology Gateways (term used in the Irish Innovation Ecosystem) are entities embedded inside an academic institution. Their goal is to engage with industrial and community partners to progress innovative concepts ideally up to high (6-7) Technology Readiness Levels (TRL) and handover services or products close to commercialisation. Achieving high TRLs is an important metric for the success of an academic-industrial partnership. Without it, early research results are not adequately exploited, the engagement is neither sustainable nor fruitful for either party as it yields no clear benefits to the industrial partner.

It is common for a Technology Gateway to be proficient in a specific field only, for instance, Material Science, Robotics or Bio health. This single-domain approach is

attractive to initiate a partnership because it offers access to deeper scientific insights. However, one may argue that the foundation for knowledge transfer is not suitable to ensure the completion of the full innovation cycle towards achieving high TRLs. Nowadays, every product or service has multidisciplinary requirements ranging from interfacing with the user, through a certain degree of expected intelligence and customisation, to networking and electronics. These topics may lie outside the spectrum of the know-how of a research team.

Photonics experts, for example, may not be aware of constraints or advances in hardware or machine learning. A satisfactory proof of concept or early prototype they provide could require complete rework or be incompatible with other components when proceeding to prototypes or alpha/beta versions of an associated device. Consequently, there is the risk of delays and budget overheads leading to loss of trust in the partnership or even the cancellation of an innovative project.

We propose that in order to ensure holistic, sustainable support in innovative partnerships from the academic side, a Technology Gateway needs to encompass multiple capabilities so as to be able to autonomously deliver end-to-end products or services to a high TRL. Within this practical network-based knowledge transfer model, we identify and justify the set of skills involved and the relationships both with the partnering organisation and within the underlying academic and research community.

We just outlined the area of interest, the issues faced and our approach towards organising innovation partnerships in a mutual beneficial manner. The next paragraph summarises previous relevant works in knowledge transfer and the specification of innovation partnerships. Paragraph 3 discusses this inside set of skills and the role of fellow, specific academic expertise. It is followed by two case studies that illustrate our work and we conclude with the overall evaluation and pointers to future work.

2 Related work

There is a distinction between Knowledge Transfer techniques *Communitites Of Practice* and *Network Transfer* models. While the former is more flexible and can accommodate multiple, compatible goals, (Parent, 2007) the latter is supported for Innovation Partnerships as it encompasses best practices, conformance with agreed obligations and results in best-added value for all partners. Capabilities to express knowledge transfer can be defined as generative (improvement through innovation), disseminative (Minbaeva, 2018) (contextualised so as to build commitment from stakeholders), absorptive (Mariano, 2015) (of external knowledge) that if present the capacity for adaptive/resposnive knowledge transfer.

From the numerous and diverse factors that influence Knowledge Network Transfer in Innovation Partnerships, we focus on the following (De Wit-de Vries, 2019): *Cultural differences* on the language used that hinder absorptive capability, *Institutional*

differences on methods that affect communication, delivery times/modes and alignment of goals, and finally, *Social Capital* that establishes trust for successful completion and early identification and reporting of issues.

There is a considerable amount of research on how to make Academic-Industrial partnerships productive (Kaklauskas, 2018). (Sadeghnezhad, 2018) reviews the mutual benefits of academic-industrial partnerships and identifies "empowerment of human resources" as an outcome of long partnerships. (Awasth, 2020) in the collaborative framework including factors such as "Identify and Appoint Suitable People", "Adopt Policies for Effective Communication and Collaboration".

Here we consider, as industrial partners, companies of different sizes and maturity, from start-ups to SMEs and large multi-nationals (Demirkan, 2015). The issues (Mazzei, 2018) to resolve are domain-agnostic and organised as.

(1) Understand current and desired TRLs.

(2) Align business & research objectives.

(3) Identify required skillset to own delivery.

Partial lack of skills relevant to the innovation effort albeit not explicit at the start becomes apparent in start-ups and also surfaces in larger companies due to shortages of communication among departments or unavailability of proper personnel. The academic partner should address this deficiency to safeguard the innovative effort.

(4) Establish Communication methods & Channels.

Although the pandemic accelerated the adoption of digital platforms, the number of different options (consider for instance the available tools for online meetings) indicates the effort to reach a consensus on the tools to be used.

(5) Negotiate and finalise intellectual property assignments.

It is recommended to fulfil this swiftly so as not to delay the start or completion of the project and frustrate technical personnel.

(6) Finally, form and sustain strategic partnerships.

Through personal mutual respect materialised by follow-on phases or projects.

3 The academic side of Innovation Partnerships

3.1 Overview

Figure 1 illustrates our approach. The full skill-set Technology Gateway (*Insiders*) is the core for the delivery of Innovation partnership and interacts both with the partnering organisation and relevant academic researchers (*Support*). The rationale behind the skill-based organisation is pragmatic. Not only does it directly relate to the execution of tasks

in projects, but it follows industry-based practices thus simplifying the collaboration and coordination with the relevant industry.

It is worth emphasising that Insiders should be domain agnostic. Although through previous projects they may be familiar with specific domains (e.g., Industry 4.0, education, agriculture, health) their agility enables to undertake innovation efforts in new domains and explore them either directly or through *Support* collaboration.

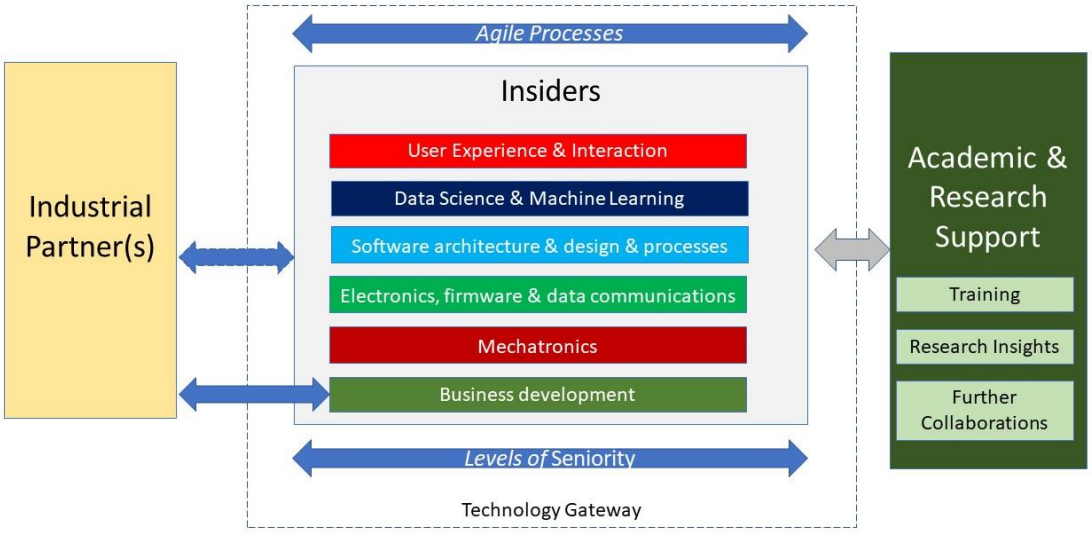

Figure 1: Core skills within the innovation ecosystem

3.2 Insider skillset

Figure 2 shows the organisation of the skills required to reach this holistic solution. The first three skills represent the full stack of a software product or service. User Experience covers interfacing, software architecture design and processes (all back-end), business logic development and deployment. We consider that nowadays and, in the future, elements of data science will be required in any product since customisation and intelligence have already become expected features thus the inclusion of Data Science & Machine Learning. Electronics are introduced to cover cases where a physical interactive device is required (e.g. an ECG or environmental sensors). Finally, Mechatronics come into play to cover cases where electronics/software control moving parts of a machine. The innovation ecosystem also benefits by the availability of mechanical engineering skills to assist with 3D design and printing, augmented and virtual reality environment creation.

All skillsets bar the last one, are technical and together have been proven to cover a high-level all aspects of development for a physical product or a digital service. Business development is added with the goals to determine the socio-economic feasibility and impact of projects, manage the progression of the road map of technical work and own

dissemination and protection of intellectual property. These are important but non-technical tasks, important to be treated separate to enable technical researchers to focus on their area of expertise.

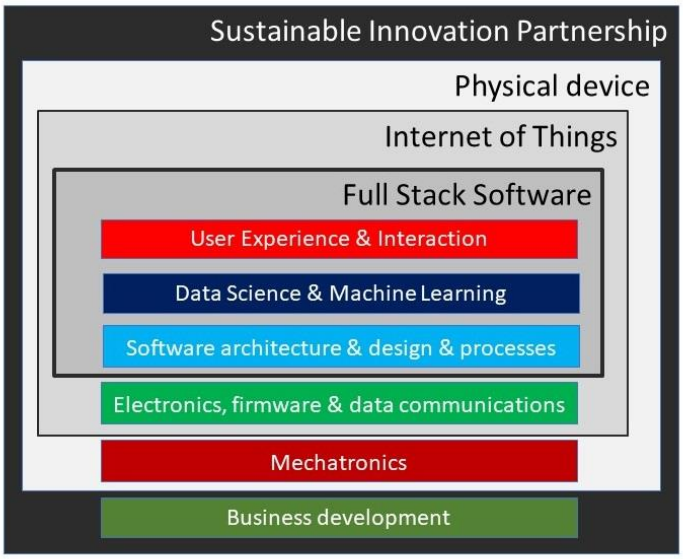

Fig. 2: Core Insider Skills

Table 3 lists the context (Ownership) for each of these skills and their main tasks of concern. This approach is scalable. These skills can be covered by an individual or a team of researchers with experience and seniority relevant to undertaken projects.

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Skillset	**Ownership**	**Sample Tasks**
User Experience & Interaction	Requirement Elicitation, Interaction Flows	Design Thinking workshops, AR/VR wireframes, rapid prototyping
Data Science	Service Intelligence & Customisation	Data pre-processing, machine learning operations
Software solutions	Software functionality up to specification	Architecture, DevOps, cloud & third-party integrations, front/back-end development, data management
Electronics	Hardware functionality up to specification	PCB Design/assembly, firmware development, power management, data communications
Mechatronics	Functioning, up to specification of mechanical parts	Enclosures, 3D printing, design and development of moving parts

Business development	Ownership of partnership, IP management	Project Management, applying for funding, compliance with standards

Table. 3: Core skills ownerships and tasks

3.3 Peripheral Support

The *Insiders'* objective is to deliver products or services to high TRLs, yet they obviously cannot fulfil all aspects of project needs especially as projects have mostly a multidisciplinary nature. A second set of skills, specific and highly proficient may be required per story or project. This Support layer is addressed by underlying expertise in the academic institution. Chemical Engineering, Process Optimisation, and Pedagogy are a few examples in an open area of domains.

Knowledge transfer issues may appear between Insiders and Support, for instance, due to different methods, goal definition, punctuality and availability, it falls to the Insiders' team, and in particular to product owners, to identify and resolve them.

3.4 Ethos & Operations

Insiders work within the Agile Manifesto and follow Scrum/Sprint practices. There are multiple reasons why this approach is beneficial. First, any Innovation/Research project has an element of unknown and having iterative cycles with progress and directional reviews, identifies and assesses risks early and asserts advancement towards commonly agreed and understood goals.

It is flexible and scalable depending on the stage and requirements of a project. Teams of "flying columns" by *Inside* researchers are dynamically formed to work and own individual project stories at different stages of project execution. For instance, a team may work on User Experience artifacts such as wireframes while another can prepare a hardware device and use Scrum meetings to coordinate.

It alleviates Institutional Differences as Agile methods are widely used in Industry (Beck, 2022), exposes researchers in best practices. De facto agility is introduced at individual, team and organisational levels streamlining the researchers' engagement with the industry community and ensuring that issues that arise in any area (from electronics to user experience) are identified and tackled early.

Moreover, this agile mentality prompts researchers to seek additional *Support* within the underlying academic institution for any specific problems not covered by this core skillset. Conversely, the academic community becomes confident of an entity that can fulfil core requirements of any project.

4 Case Studies

4.1 Appliance to validate the operation of a medical Device

The partner company developed a medical device and required the execution of (duration of a number of weeks) simulated scenarios to comply with regulatory standards. Within a partnership, an appliance was developed to configure and execute these scenarios by controlling and moving parts so as to simulate body functions and measure the performance of the device. Support expertise was involved for regulatory compliance and state machine modelling.

The project was delivered in four phases of progressing TRL from 4 to 7. Iterative delivery-built trust through regular releases by the Insider scrum team, simplified handover, increased involvement by the engineers of the partner company and managed the initial scope creep by product and sprint backlogs.

4.2 End of factory line robotic arm

The objective was to produce a robotic arm which would detect through computer vision, bottles appearing at the end of the production line, pick them up and place them in the box until this was filled and then start with a new box. The challenges included the identification of the bottle size, its optimum placement in the box to achieve maximum capacity and the completion of the task with speed greater than the supply of incoming bottles. As mentioned previously, different phases of the project reflected gradual progress to TRL 7. Industrial automation and computer vision expertise was provided by *Support*.

The principal investigator acted as the product and backlog owner. Three scrum teams were formed, the first one around electronics and mechatronics, the second over computer vision and the third on system integration. Each of these teams included a liaison researcher, (for instance a software architect in the first team to monitor compliance among tools developed) and had their own internal releases with product releases on a quarterly basis. Apart from delivering the project, this effort boosted the confidence of researchers as the final outcome was a physical device built to a high level of complexity not normally accommodated by their level of expertise and experience.

5 Evaluation

This approach for the formation of a Technology Gateway is explicit and framed without the complexities and risks of the Communities of Practice approach. It is easily to replicate, manage, maintain and scale as any of the core skills can be addressed by an individual or teams of researchers with appropriate seniority and experience.

The impact is manyfold. Researchers are exposed to industrial best practices especially Agile processes (and empower any potential transition to industry). Strategic, successful and long-term partnerships are formed as innovation efforts move steadily and progressively towards high TRLs. And finally, industry finds a reliable academic partner where communication is clear, direct access to further expertise is provided, levels of expectations are understood, and work practices are shared.

The core skillset for Insiders is selected so as to cover digital services in the form of a software platform, IoT devices with hardware, network and software components and full devices with mechatronics support. It establishes a clear demarcation point for a research entity to autonomously manage an Innovation Partnership. Whenever a project requires more in-depth skills in an area outside this skillset, the agility acquired enables these Insiders to seek and receive insights from their research community.

6 Conclusions and Recommendations

Apart from the two aforementioned case-studies, this model has been successfully applied in more than 200 Innovation projects at the Nimbus Technology Gateway, Munster Technological University, Ireland. In the cases where any of these *Insiders* skills were either not present or not included in the Scrum teams, we experienced either delays in delivery or missed/misjudged critical requirements or constraints of the project.

The domain-agnostic characteristics promote an ethos of innovation and a culture of "controlled failure" where researchers are encouraged to explore new application fields, methods and techniques. Yet, this openness causes a constraint regarding the applicability of this model into industry-located research. A research centre of an organisation operates in tighter, well-defined settings and does not have straight academic support lacking the elements required to implement our approach.

Future research work involves the deeper integration with the process of the industrial partner and the formation of an outer core layer of Collaborators within the academic community who share and understand this approach.

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Partnering for Transformation - exploring the concept of Transformative Academic Institutions

Madeline Smith[1], Patricia Canto-Farachala[2], Emily Wise[3]
with contributions from[1]

[1] The Glasgow School of Art, Innovation School, UK
[2] Orkestra, Deusto Foundation and Deusto Business School, Spain
[3] Lund University, CIRCLE and Collaboration Office, Sweden

Abstract
Academic institutions are frequently called on to evidence the impact they have on their regional ecosystems whilst at the same time respond to the expectations that they produce globally significant research. This often results in tensions because of the different drivers and rewards of these dual ambitions.

This exploratory research project describes how international academic partners across five institutions came together to discuss and further understand their experience of trying to balance these different demands to produce both robust academic and societally impactful results. The iterative process started with exploratory and sharing workshops, before development of case studies for each partner perspective, a collaborative workshop to identify challenges and opportunities, and final reflections on learning and further research.

The partners had all (within their own contexts) looked to demonstrate and enhance the societal impact of the research activities through working collaboratively with other territorial partners (government, industry, civil society) to define their research agendas embedded in the priorities of their regions and focused on understanding, defining, and addressing key regional challenges. Thus, by delivering "regionally responsive research" to address these complex societal challenges they aimed to become Transformative Academic Institutions (TAI). Whilst resonating with the proposed concept of TAI, the partners brought their individual context and experience to the discussions. This uncovered challenges and differences (in context, in institutional models, in local stakeholder relationships, and even in approach).

This early-stage research describes how through a participatory and reflective process of working papers, sharing workshops, and collaborative knowledge building, the five institutions explored and progressed towards better defining the significant factors, challenges, and opportunities for TAI approaches – and reflecting on how respective institutions might develop their transformative partnering capacities in the future.

Keywords
Transformation, regional innovation systems, collaboration, societal engagement, co-design

1 Introduction

Universities are increasingly being seen as a positive vehicle for territorial development and regional transformation yet are challenged by balancing priorities and resources to

actively engage with external actors to address societal challenges while simultaneously delivering on academic excellence.

This exploratory research brings together five international academic partners to understand their experiences of genuine partnership for change within their regions. The partners all consider societal engagement and collaboration as a reciprocal interactive process based on mutual knowledge creation and dissemination (rather than a unidirectional transfer process), implying that interaction and reciprocity is a key fundamental in societal collaboration, and have identified a common interest in exploring this approach and how it can be operationalised.

The project partners (Orkestra, Basque Country, Spain; Innovation School, The Glasgow School of Art, UK; The University of British Columbia (UBC), Okanagan, Canada; Competitiveness Institute - Catholic University of Uruguay; and Collaboration Office, Lund University, Sweden) all have ambitions to enhance the societal impact of research through working collaboratively with other territorial partners (government, industry, civil society) and defining their research agendas to focus on detecting, understanding and addressing key regional challenges.

While the partners have different organisational structures (from mission-oriented research centres to university departments, to groups of researchers sharing an interest in undertaking socially relevant research), they all undertake research collaboratively with communities in their regions to identify, explore and address challenges.

By delivering "regionally responsive research" to address complex societal challenges, they identified with the concept of Transformative Academic Institutions (TAI) (Aranguren et al., 2021). This early-stage research project describes how through an interlinked series of working papers, workshops, and collaborative knowledge building, the five institutions are progressing towards better understanding what it means to be a TAI by defining the significant factors, challenges, and opportunities for TAI approaches. The results from this exploratory work point to a more strategic partnering with external (non-academic) actors in order to contribute to (longer-term) change processes that address regional challenges. This can take universities beyond their existing roles in collaborative production and dissemination of knowledge towards new roles in curating learning and catalysing change.

Following this introduction, the next section reviews underpinning literature on the evolving role of HEIs in relation to societal development. Section 3 provides an overview of the approach and methods used in this exploratory research. Results are presented in Section 4, followed by a discussion of results (Section 5) and conclusions (Section 6).

2 Background and underpinning literature

Universities are seen as key players in territorial development since the discussion around innovation and economic growth emerged in the late 20th Century. The discussion was

born in the context of the Japanese economic miracle, explained by the capacity of its firms to learn and innovate (Freeman, 1987) and when an innovation gap was identified in the United States' industry due to the rise of competition (Etzkowitz, Webster, Gebhardt, and Terra, 2000). The national systems of innovation literature explains innovation as a result of a non-linear interactive process among firms, universities and public institutions (Edquist, 1997; Freeman, 1994; Lundvall, 1992; Nelson, 1993), and the regional systems of innovation literature explains different economic outcomes within countries through territorially specific dynamics (Cooke et al., 1997; Morgan, 1997).

In placing universities at the heart of the innovation process, the systems of innovation literature paved the way for the emergence of new concepts and frameworks aimed at capturing a new role or third mission for universities in addition to the more traditional ones of teaching and doing research. The influential Triple Helix Model (Etzkowitz and Leydesdorff, 1998) identifies the intersection of university, industry, and government relations as an environment conducive to innovation, with those relations requiring a constant reconfiguration for the production, transfer, and application of knowledge (Ranga and Etzkowitz, 2003). In this early model universities develop their third mission by transferring scientific and technological knowledge to firms and industry.

However, developing a third mission (Laredo, 2007; Nedeva, 2008; Pinheiro et al., 2015) depends on different contextual factors (Jongbloed et al., 2008, Laredo, 2007) making it necessary for universities to adapt their roles to the different contexts (Tdtling and Trippl, 2005). Uyarra (2010) identifies 5 different third mission models as they are reflected in the literature according to their type of engagement and contribution to regional innovation: knowledge factories, relational universities, entrepreneurial universities, systemic universities and engaged universities. Nuanced approaches to the latter type are civic universities (Goddard, 2009), responsible universities (Sorensen et al., 2019) or developmental universities (Arocena, et al., 2017). Similarly, entrepreneurial universities defined early on as engines of growth through knowledge capitalization, creation of new firms (Etzkowitz, 2001) and by facilitating behavior to prosper in an entrepreneurial society (Audtresch, 2014), are found to play different roles at different levels and to change those roles over time. They can be: (i) growth supporters, through knowledge and innovations; (ii) steerers of regional development by building networks and complementing other local organisations; and (iii) growth drivers through leadership and their capacity to respond to regional needs (Pugh et al., 2022).

In any case, the literature on regional systems of innovation highlights the importance of proximity and this has intensified pressure on universities to play active roles in their host territories (Aranguren et al., 2016). In Europe, the requirement by the European Commission that all regions develop coherent territorial development strategies (known as Smart Specialisation Strategies, S3), as an *ex ante* condition to have access to structural funds since 2012, has contributed to reinforce the role of universities as key players in territorial strategies for economic growth (Goddard, 2009; Goddard and Pukka, 2008; Goddard Kempton and Vallace, 2013; Kempton et al., 2014). Through the Entrepreneurial Discovery Process (Foray, David, and Hall, 2011), many universities in

Europe have engaged for over 10 years in collaborative multilevel processes aimed at defining territorial strategy. This has resulted in a wide array of university engagement practices that respond to specific contextual factors (Canto-Farachala, P., Wilson, Arregui-Pabollet, E. in press). This track-record of collaboration for innovation if revisited, could contribute to address sustainability challenges (Miedzinski et al., 2021).

The world's sustainability challenges are listed in the United Nation's Agenda 2030, that includes Higher Education Institutions (HEIs) as actors that can work in partnership with others in collaborative processes leading to the achievement of the Sustainable Development Goals (SDGs). However, as Cuesta-Claros et al. (2021) note, while the SDGs provide a shared vision of a sustainable future, there are multiple ways of understanding sustainable development transformations, the role of universities in those transformations and the changes needed within universities to bring them about. Pluralistic research environments that enable inter and transdisciplinary approaches are needed (Greenwood and Levin 2007; Bornmann 2013; Karlsen and Larrea 2014; Schneider et al., 2019), which in turn require a new set of incentives that recognize engagement in career progression indicators (Benneworth, P. 2017; Watermeyer 2015; Reale, et al., 2017). In any case, complex societal challenges acquire meaning through interactions in the local context, where universities can contribute to create spaces in which alternative ideas, practices and social relations can emerge to further sustainability transitions (Wittmayer, 2014). These are spaces in which to develop a shared language and meanings that can lead to shared agendas for action (Karlsen and Larrea, 2014). A university model proposed for sustainability that predates the agenda 2030 is the transformative university, based on an alternative mission of co-creation for sustainability in a given geographical vicinity (Trencher et al., 2014).

In addition to the above, the decade of austerity that followed the 2008 financial meltdown increased demands for explicit evidence of the value of public investment in research and higher education. The economic consequences of the pandemic and the ongoing war in Ukraine may exacerbate that trend. In this context, researchers are increasingly asked to demonstrate the contribution of their projects to society and the economy in exchange for public funding (Fogg-Rogers, Grand, and Sardo, 2015; Watermeyer, R. 2019). This has brought forward the need to evidence pathways to impact (van den Akker and Spaapen, 2017). The so-called metric-tide (Wilsdon, 2016), however, has tended to reinforce an understanding of societal impact based on linear models of innovation and communication (Sivertsen and Meijer 2020) that do not help to capture emergent and multidimensional research processes. Moreover, research can also have negative impacts on society (Derrick et al., 2018; Sigurdarson 2020).

In sum, universities and Higher Education Institutions (academic institutions hereinafter) are increasingly seen as curators of learning, knowledge and thinking, as well as catalysts of change and sustainable development (Trencher et al., 2014; Aranguren et al., 2016; Benner and Schwaag Serger, 2017; Weber and Newby, 2018; Schwaag Serger et al., 2021; Aranguren et al., 2021; Cuesta-Claros et al., 2021; Pugh et al., 2022, Benneworth

and Fitjar 2019). They are expected to play a significant role in building productive multi-stakeholder partnerships within their local socioeconomic environment, engaging with companies and other actors to drive sustainable transformation processes. The aims of these multi-stakeholder partnerships are not only the production and dissemination of new knowledge (research and education), but also societal transformation. There is a need for a more realistic, honest understanding of the limitations of universities' contribution as local actors in their places, one which does not downplay the internal tensions and external barriers on their ability and willingness to engage (Kempton, 2019; Kempton et al., 2021).

3 Methodology and approach

The research involved an iterative process of exploratory cross-case learning between the five partner academic institutions on three continents (See Table 1) This participatory approach aimed to understand and unveil a better definition of factors, challenges, and opportunities, as well as preconceptions and assumptions around partnering for transformation. In such participatory research, while the project may still start with a question and end with an answer, the process involves iterative, ongoing interaction and dialogue between relevant stakeholders, who all contribute towards a possible solution. Bringing together a diverse range of people with a shared interest or collective motivation and supporting them to collaboratively address a complex set of challenges (Norman and Verganti, 2014) can allow for insights and ideas to be shared, developed, and applied to inform new products, services, systems, and experiences that respond to communities' ideas and aspirations (Sanders and Stappers 2014).

Table 1: Participating institutions

Department	**Organisation**	**Location**	**Research Focus**
Innovation School	The Glasgow School of Art	Glasgow, UK	The Innovation School is a leading centre for design teaching and research that applies Design Innovation to the key issues defining contemporary society. We examine design's role as a catalyst for positive change. Our research uncovers how to frame and create the 'spaces' for such collaborative engagement, bringing together participants' experience to reimagine and co-design implementable solutions, and the identification and implementation of innovative responses to complex issues through an open and collaborative engagement with communities, publics, and stakeholders.
Orkestra	University of Deusto	Basque Region, Spain	Through transformative research, Orkestra links global and local knowledge to foster innovative solutions to the challenges of competitiveness faced by the Basque Country. We do so hand in hand with the

			territorial actors directly involved in those challenges, thereby co-generating actionable knowledge useful for their decision making. The specific goals set out in our mission are: (i) to contribute to improve Basque Country competitiveness, (ii) to promote the improvement of citizen's wellbeing and, (iii) to create knowledge on regional competitiveness.
Collaboration Office	Lund University	Lund, Sweden	LU Collaboration is a department within the university's administrative section for research, collaboration, and innovation, with the role of promoting collaboration between the university and societal actors. Our work takes its starting point in global societal challenges where the university has a key role to play, together with others, in order to contribute to new knowledge, new solutions and innovations. The department assists with coordination, communication, skills development, action research and other tasks that support the initiation and development of cross-faculty projects and platforms where university researchers or students collaborate with external actors (e.g., companies, municipalities and other public sector actors, research funders and other organizations).
Social and Economic Change Lab	UBC	Okanagan, Canada	In the lab, a multidisciplinary group of faculty, staff, and students across UBC focuses on social and economic change in regional, national, and international contexts. Connecting diverse perspectives, ways of knowing and understanding, they generate critical knowledge to address complex challenges facing individuals, organizations, and communities.
Competitiveness Institute	Catholic University of Uruguay (UCU)	Uruguay	The Competitiveness Institute is a research center within the Business Department at UCU, concerned with competitiveness enhancement at different levels (country, regions, clusters, firms). It has a specific mission to promote an active space for the reflection, creation, and dissemination of knowledge on competitiveness, public policy, strategy, and innovation. Through its interaction with different regional stakeholders the Competitiveness Institute seeks to contribute to reality transformation and the improvement of wellbeing at the region.

The group of partners had been brought together by a common interest in how their research could bring impact and change in their regions with the aim of developing an 'informal sharing space' to discuss the local/regional/territorial impacts of research. Such research is a journey of inquiry, "where direction, conduct and action are not

predetermined, rather they are chosen through observation, reason and evidence, informed by feeling and sensitivity, as the journey progresses." (Culver et al., 2015: 205-206).

The iterative process started with exploratory and sharing workshops, before development of reflective case studies for each partner perspective, a collaborative workshop to identify challenges and opportunities, and final reflections on learning and further research.

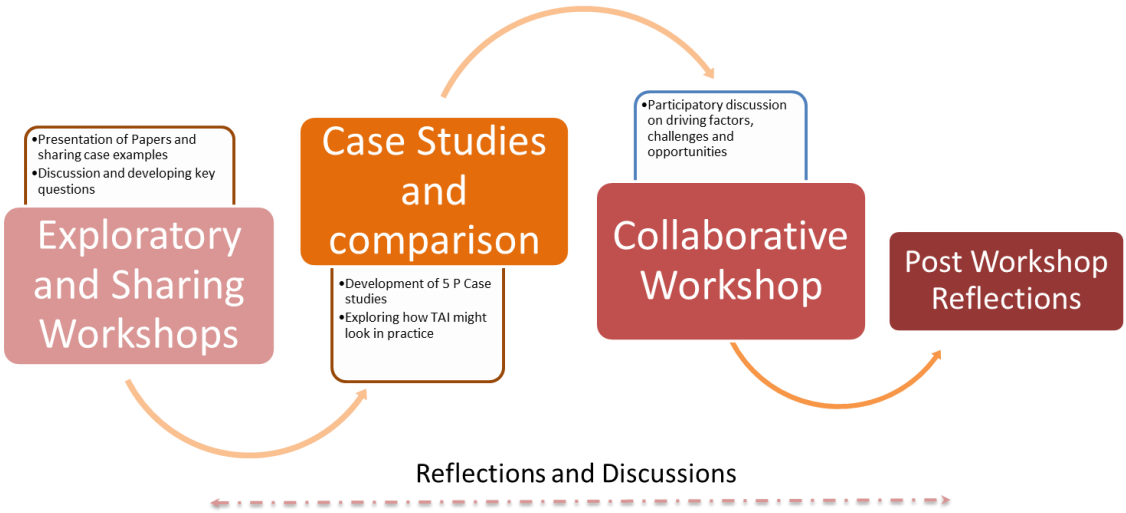

Figure 1: Exploratory research approach

1. Exploratory workshop (May '21)

As an introduction and an initial prompt for discussions, Orkestra (Basque Country) shared a position paper they had developed to articulate some of the challenges and ambitions in this approach "*Transformative Academic institutions: An experimental framework for understanding regional impacts of research*" **(**Aranguren et al., 2021) in advance of the first workshop, and this was presented and discussed. This paper aimed to contribute to discussion on societal impact of research, proposed and an experimental framework to map the relationship between an academic institution's role in a global academic knowledge community and their role in the (local) practical knowledge community, and proposed a definition of **Transformative Academic Institutions** as research centres with a mission to proactively engage in the socioeconomic development of their regions.

This exploratory session was used to gather reactions to the paper, and reflections on how it resonated (or not) with partner experiences. This therefore stimulated debate and prompted reflections on similarities and differences in each context. The initial reaction was very positive, with participants describing how their experience resonated with the postulated model. The workshop concluded with agreement that the partnership should

continue this exploration and started to develop research questions for the group to address collectively.

2. Sharing workshop (June ‘21)

This workshop was structured around tangible shared examples from two partners (Innovation School, GSA and Competitiveness Institute, Uruguay) of how research impact is captured, particularly evidencing value for societal partners and for academics. This contribution had been prompted during the previous discussion on how we were valuing our contribution, and who was defining and evidencing that value.

The GSA example described the recent exercise in developing an impact case study (ICS) for the Research Excellence Framework (REF) submission and assessment. In this context impact is defined as “an effect on, change or benefit to the economy, society, culture, public policy or services, health, the environment or quality of life, beyond academia” (UKRI, 2021), and aims to articulate the difference we make and the evidence for the difference we make or have made (Boddington 2021). The ICS focused on how using participatory and co-design processes helped to improve user experiences for health and care services across Scotland, through supporting the development of new services and technologies, providing a lived-experience evidence base for health and care decision making and intervention development, and supporting health and care professionals to engage more effectively with stakeholders. The case also highlighted the challenges in evidencing such value (this happened because of us) and the academic demand to anchor in research, which can still be a challenge for action research approaches.

The Competitiveness Institute, UCU case explored how they keep track of impact and uncovered some of the main challenges they face both within and outside the University. The institute seeks to “transform our reality, contributing to the enhancement of Uruguay’s competitiveness,” by conducting applied research and consultancy projects working in strong linkage with different regional stakeholders. Tracking impact included evidence and publications, but also invitations from industry, government and NGOs to discussions and action, as well as societal contribution to the debate (and measurement) of competitiveness in the country. Challenges included the (still) poor linkages between firms and academia (particularly for social research agendas), as well as the internal prioritisation of academic outputs, and a lack of institutional flexibility. The specific example of the state competitiveness in Uruguay report showed strong social impact, influencing debate and action, but still challenges with being valued within the institution specially in regard to accountability matters and the evaluation of individual researchers.

This led to further discussion and defining of the research questions, with an initial focus on “What does it mean to be a Transformative Academic Institution?”

3. Subgroup Analysis

Whereas the first two workshops had been good opportunities for sharing experiences and had generated significant discussion of ideas and an initial defining of research questions, it was felt to be helpful for a smaller group to progress streamlining and facilitating the process for identifying areas to focus on for further discussion. As such it was decided that a smaller group would help analyse the discussions and outputs so far and proposed a more structured approach (whilst still remaining open and iterative) to take forward the debate (and generating knowledge in the process).

A subgroup was therefore established, involving all institutions, who analysed the outputs so far and designed the next stage for exploration.

As a further contribution, each partner was invited to develop a mini case study to articulate their TAI experience including reflections on their roles in territorial impact, using a common framework (the 5 P's) to briefly capture the following areas:

Purpose
: Why were we doing this and what are we aiming to achieve?

People
: Who was involved and who was interested in the outcomes?

Practice
: What did we do and put in place, and any immediate outputs?

Performance
: How are we progressing towards our ambition and any outcomes?

Problems/possibilities
: What challenges did we encounter, what could be improved, what did we learn?

It is worth noting that developing the case studies stimulated some challenge in itself as partners felt they were still discussing what transformative meant within their own context, how much agency they had to articulate this within their institutions, and indeed who defines value within territories and communities (who may not agree on that definition), but this feedback in itself was informative for the overall debate on how universities and researchers can situate themselves in that conversation.

4. Collaborative Workshop (November '21)

Case narratives were then analysed to explore similarities and differences, and other key insights (see results section below), and the outputs from this analysis were shared in advance of the final stage using collaborative online tools (MIRO), allowing the wider group to add further reflections and contributions.

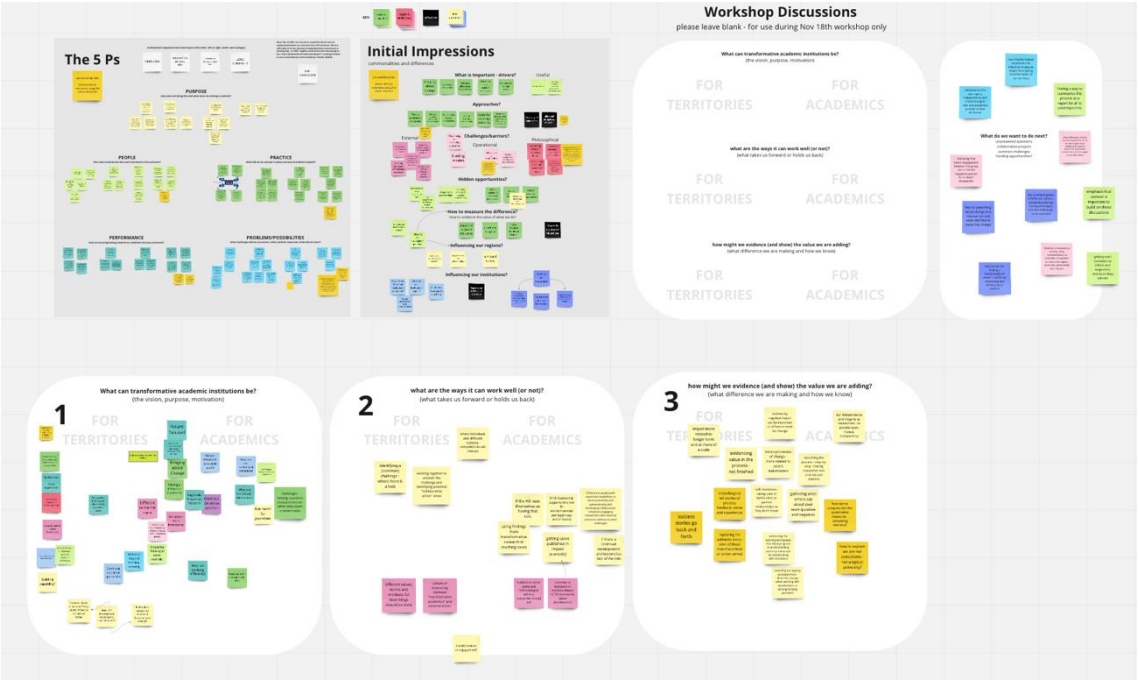

Figure 2: Overview of Miro collaborative workshop

The wider group from across the institutions then reconvened for the final collaborative workshop, involving shared online tools, and facilitated discussions on structured questions (both in cross institutional breakout rooms, and together in plenary). The aim of this process and activity was to develop a greater shared sense of the challenges and opportunities for HEI territorial impact, from which to develop shared questions or briefs in view of further research and options for collaboration to explore new ways of tackling these challenges and opportunities.

As well as an initial discussion on the analysis of the outputs so far and the case study development, this third workshop was structured around exploring three further questions to delve deeper into our common (or not) understanding of TAI, how to make it practical and deliverable, and how to measure success. These questions were:

What can transformative academic institutions be?
(the vision, purpose, motivation)

What are the ways it can work well (or not)?
(What takes us forward or holds us back)

How might we evidence (and show) the value we are adding?
(What difference we are making and how we know)

As well as notes from the facilitators (volunteers from each institution led the discussion in each breakout group), the online workshop was recorded and transcribed so that nothing of the richness of the debate was lost.

5. Final reflections (post workshop)

The final outputs from the research were collated and shared, before a short, structured feedback was collected from across the partners with reflections from participants on the process, key learning, and opportunities for further research. These final considerations allowed for post workshop reflections and have contributed greatly to the discussion and conclusions below.

4 Results

The early workshops involving discussion of the position paper and sharing of specific cases triggered an initial positive response across the partners who identified with the experiences being described. As the discussion unfolded, however, this also uncovered challenges and differences (in context, in institutional models, in local stakeholder relationships, and even in approach).

Case study analysis of the 5P exercise looked at similarities and differences across the institutions. This highlighted important factors for success, including a real focus on bringing about change, working collaboratively with partners, and focusing on key regional challenges. There was also a strong theme of establishing independent credibility whilst being connected to the real world. This also highlighted barriers to this approach, for instance the difficulty to change some mindsets in academia, especially at strategy or mission definition levels, the issue of accountability (and agency) and the challenge of evidence collection to show the value of the approach.

Despite a diversity of approaches (reflecting the multi/interdisciplinary nature of this research partnership), there was common emphasis on bringing in external knowledge and supporting partners through a change generation process. There was also a strong commonality around ensuring flexibility within the process (to adapt to different needs and requirements) and building a mutual learning environment. This last point was raised by some partners as extremely important emphasising that creating liminal spaces where communities and universities can engage and find new ways of imagining the world was the only way to create a new future. This reflects thinking by Howard-Grenville et al. (2011), in their description of an in-between space where the personal and the public, the possible and the ambiguous, the familiar and the unfamiliar, the existing and the new are explored.

Challenges with this approach also highlighted some commonalities, in particular, developing credible ways to measure impact, the importance of evidencing intangible outcomes and influence, and ensuring an ongoing dialogue to meaningfully include stakeholders.

From the final collaborative workshop, these themes were further debated and then input into the three question areas described above. Key findings are summarised in Table 2 below.

Question exploring TAI	Key elements of success	Challenges
What can transformative academic institutions be?	Making a difference for partners/bringing about change; being future-focused; vision to respond to societal challenges; being open to new ways of thinking; building capability and prioritising regionally responsive research.	Institutional constraints and agency; the marketization of transformation; ensuring genuine engagement; ethical tensions and prioritising institutional ways of thinking.
What are the ways it can work well?	Identifying a common challenge; using findings in teaching cases; developing collaborative initiatives; active support from HEI leadership.	Lack of institutional support; lack of legitimacy; not valued through traditional research rewards; difference in values, norms, and mindsets
How might we evidence the value we are adding?	Evidencing the value in the process; gathering what others say about your work (positive and negative); capturing the authentic story; impact over the longer term	Nurturing partnership; maintaining independence and integrity; stories of change competing with quantitative measures; difficulty in evidencing influence.

Table 2: Key findings from the collaborative workshop

The discussion also highlighted some further questions including impacts are always positive or can TAIs contribute to a negative outcome for certain communities (for example reinforcing dominant narrative for socio-economic models). This raised the importance of disruption and bringing in different thinking and perspectives as part of the essence of TAI approaches.

5 Discussion

This exploratory research found that, while the concept of a TAI resonated with the experience of those involved, there was not an agreed view of what transformative could mean, and indeed if it is the correct term. The iterative workshop approach allowed the partners to share experiences, challenge each other's thinking, articulate what is important for a TAI (vision, purpose) and how that can be supported to build effective partnerships within their ecosystems. As Karlsen and Larrea (2014) suggest, dialogue in the context of diversity is not necessarily a process that leads all participants to think the same; it is mutually shaping, allowing participants to gain a better understanding of each other.

Indeed, the participatory design approach allowed a group of researchers, working in different contexts and in very different organizational settings, to tackle questions in a novel way and deepen their collective understanding of what they are trying to achieve as university researchers. The research process unveiled and challenged assumptions around concepts of "transformative," "HEI," and "impact" with some suggesting the need to pause and build a shared language as a necessary step to creating shared meanings and eventually a shared agenda through the interactive workshop process the group has been developing.

This also raised the need to rethink (and perhaps reimagine) the purpose and remit of universities and might lead to alternatives to the very notion of Transformative Academic Institution. In any case, what this process reveals are that while labels and concepts help to frame discussions around roles, research approaches, governance structures, and incentives, among others, self-reflection is key because it helps to develop awareness of what is being done, why and by whom. Moreover, the international dimension of the research process is a counterweight to the danger of matching research with local needs that can lead to it being detached from experiences and processes happening elsewhere and 'locked in.' This research process began with the recognition and feeling that new forms of 'internationalisation' can be built by linking research processes in different territorial contexts and learning from and with each other.

The discussion also highlighted a possible tension between existing (and well-embedded) HEI roles of knowledge development and dissemination for and with society, and the new/evolving call for HEIs to act as curators and catalysts or facilitators of change processes. Questions were raised around the mandate for and relative focus of acting as a TAI given existing resourcing, structures, and incentives. In addition, during the process of the research, participants challenged the assumption that impact from universities is necessarily always positive highlighting the need to continually interrogate it, since impact can also be negative particularly for communities not engaged or included within the usual discourse. This in itself drew out the importance of the role of universities to challenge current models and disrupt conventional thinking by bringing in different perspectives. Furthermore, all partners agreed that universities have an important role to play in future thinking, a role captured in the notion of University 4.0 by Kempton et al. (2021).

Notwithstanding their different organizational contexts, the partners included in this research have two main things in common: a mandate or interest in undertaking socially relevant research and their small size in relation to the wider university structure. Acknowledging that it is very difficult to extract conclusions from the small number of participants in the research process, they do span three very different geographies: North America, South America, and Europe. In all cases, a gap emerges between the discourse in policy circles (on the role for universities in Smart Specialisation, SDGs, etc.) and practice, where TAI approaches are still small, at times experimental and not institutionally embedded.

6 Conclusions

This exploratory research involved an iterative process of sharing, comparative case analysis and collaborative knowledge building. Through cross-case learning between five academic institutions on three continents, the partners progressed towards better defining significant factors, challenges, and opportunities for TAI approaches, as well as unveiling preconceptions and assumptions around partnering for transformation.

Alongside exploring approaches to achieve regional impact through transformative research, the project raised the challenge of legitimacy in research teams taking forward these agendas, exacerbated by the different organisational structures underpinning each partner (ranging from separate departments to looser research groups) all operating as smaller, innovative parts of their larger host institutions. Challenges also remain around evidencing the value and impact of such approaches (both for stakeholders and within academic contexts).

The exploratory research has inspired a desire for continued peer learning in order to proactively work on developing institutional awareness and conditions for taking on the transformative role, as well as acting as a collective sounding board for collaborative exploration of these challenges.

Increasingly, there is an understanding that regionally embedded research institutions can play a key role in contributing to regional socioeconomic development by aligning research objectives with the strengths of the region and collaborating with local partners to jointly develop and capitalise on region-specific competencies (European Commission, 2014). However, there is also a need for a more realistic, honest understanding of internal tensions and external barriers to the ability and willingness of universities to engage (Kempton et al. 2021). This paper offers a small contribution in that direction.

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TRIZ Reverse – A Systematic Approach To Exploit The Economic Potential Of Patents

Silvia L. Popova[1], Swen Günther[1]

[1] HTW Dresden, University of Applied Sciences, Faculty of Business Administration

Abstract

The current paper deals with a reverse invention method called TRIZ Reverse. It inverts the standard TRIZ approach researched by Genrich Altshuller (1984). Over the past few years, the methodology has gradually been developed and is currently being optimised by the University of Applied Sciences Dresden (HTWD) in Germany. An improvement of the key word list utilised as well as an analysis of code creation patterns have contributed to an increase in the quality of the results. The method at hand can be used to systematically analyse and exploit patents. Therefore, the authors of this paper recommend that technology transfer coordinators and other experts in the area of patent exploitation consider incorporating TRIZ Reverse in their toolset for innovation acceleration as well as knowledge and technology transfer.

The top priorities of current and future developmental aspirations regarding TRIZ Reverse are to enhance the utility of the single process steps, the efficiency of the patent analysis procedure as a whole, and the identification of alternative application fields of protected intellectual property as a support mechanism for the patent holders. In order to illustrate the procedure, two comprehensive case studies – analyses of patents of the HTW Dresden and the Max Planck Institute for the Physics of Complex Systems – with the aim of alternative industry technology application have been conducted. The main objective was to improve the methodological approach of TRIZ Reverse, which had previously been introduced during the TRIZ-fest2021 (Popova/ Günther et al., 2021).

Keywords

TRIZ, Reverse Inventing, Technology Transfer, Patent Analysis

1 Introduction

Given the fact that ‘only three to five percent of the patents applied for lead to economic benefits in Germany (Klein, 2014), the current status offers a huge profit generation opportunity for all actors involved in the areas of innovation, patent exploitation, and knowledge and technology transfer as a whole. Furthermore, the German Economic Institute (IW) estimates that ‘the German economy is sitting on unrealised assets of at least eight billion euros’ (Lange, 2007). Hence, it is necessary to develop promising systematic knowledge and technology transfer tools to increase expected returns on investments in research and development activities.

In this regard, the potential of the TRIZ Reverse method as a tool for innovation acceleration, the use of which enables a systematic analysis of patents in order to find

new fields of application, is to be investigated in this study. The derived 7-step approach facilitates knowledge and technology transfer from universities and research institutions to the industry, and could potentially accelerate it. The research is based on several suggested proposals for the use of TRIZ 'in reverse', which are already publically available, e.g. Ngassa et al. (2003), Glaser & Miecznik (2009). Despite its efficient application, TRIZ Reverse has until now remained an untapped resource.

According to the motto 'solution seeks problem', new application areas (i.e. problem areas) can be identified based on a known technical solution. The case studies of HTW Dresden (HTWD) – presented in the third chapter – provide an overview of the possible benefits of its application. In this context, Mann's proposal of a 'principles-based patent search' (2006) serves as a main basis, including instructions on how to connect search terms or key words from patents with the inventive principles from Genrich Altshuller's 'TRIZ contradiction matrix' (1984).

With the support of TRIZ Reverse, up until now seven patents (university internal and externally owned) have been analysed with the aim of supporting technology transfer. The most successful application of the algorithm so far was for a university-owned patent from the Faculty of Agriculture/Environment/Chemistry (DE102017123891). As a result, a project to validate the technology was initiated. In addition, a patent from the Max Planck Institute for the Physics of Complex Systems has being analysed in-depth. Transfer possibilities and opportunities are currently being discussed with the intellectual property owners. In order to promote the application of the TRIZ Reverse method and increase the possibility of technology transfer in various research organisations and companies, the authors have participated in various networking events (e.g. Sächsisches Transferforum). Contact has been established with relevant enterprises and SMEs, e.g. Procter & Gamble and Matabooks (an HTW Dresden start-up company), which in turn has recently attracted further the interest of the economic ministries of the state of Saxony, especially the State Ministry for Higher Education, Research and the Arts (SMWK).

Before outlining TRIZ Reverse in detail, it is important to look first at the variety of technology transfer tools (TTT) available on the market. The following chapter shall provide the necessary overview and enable a better understanding about the benefits and most favourable application fields of the different options. In conclusion, a comparison matrix is presented for the relative evaluation of TRIZ Reverse.

2 Technology Transfer Tools: Status-Quo

2.1 Overview of Technology Transfer Tools (TTT)

In order to create an overview of Technology Transfer Tools (TTT), the descriptive-comparative method was used as a base reference for a qualitative analysis. The descriptive method aims to deliver information about the characteristics of an entity or

phenomenon. The description can be either qualitative or quantitative (Sekaran, 2003; Garzon/ Günther et al., 2021).

The following steps were performed for the purpose of the research process (Garzon/ Günther et al., 2021):

(7) Collection of information from scientific documents from print and digital sources. In terms of the latter, the following academic databases were used: Emerald, Jstor, Oxford journals, Proquest, Researchgate, Sage books, Sage journals, Sage premier, Science direct, Scielo, Springer palgrave books, Springer link journals, Taylor and Francis journals and Wiley online library. Additionally, websites specialised in the subject were used. Searches were performed using keywords and key phrases such as Knowledge Transfer, Technology Transfer (TT), Technology Transfer Methods, Technology Transfer Tools (TTT), Technology Transfer Instruments.

(8) Selection of the documentary material, which has been obtained by reviewing abstracts and conclusions to define their relevance to fulfil the research purpose.

(9) Literature analysis and design of the conceptual framework for the study.

(10) Construction of the research approach and methodology for information analysis.

(11) Definition of variables and criteria, supported in the general characteristics found for each TT tool in the literature review.

(12) Analysis of the information using a systematic comparison methodology by means of a contrast matrix, taking the variables and criteria in point 5) as the elements to be compared.

(13) An additional cluster analysis using statistical software was performed to have another practical-comparative perspective with the aim of finding a classification of tools according to their features.

A study of the scientific literature included in the analysis revealed that several terms overlapped, such as 'method', 'instrument', 'tool', 'approach' and 'channel'. In order to carry out a constructive comparison, 'tools' were considered to be the elements which operationalise the process of Technology Transfer (TT) by means of their very own execution. In simple terms, TTT trigger the processes which link technology resources to business objectives (Phaal, R. et al., 2001; Garzon/ Günther et al., 2021).

Based on a literature review, certain elements were identified, which can be designated as 'tools' according to the aforementioned definition. The selection of findings is depicted chronologically in Figure 1 (Garzon/ Günther et al., 2021).

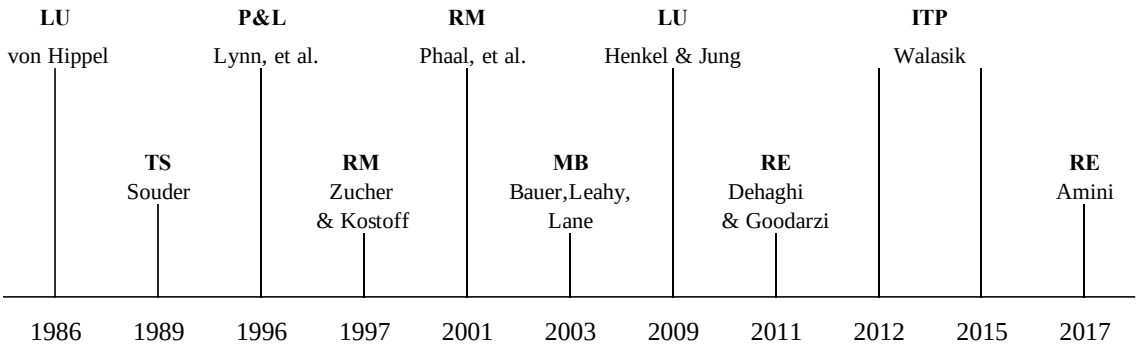

Fig. 1: Tools included in the study – Chronological perspective (Garzon/ Günther et al., 2021)

(1) Lead User (LU) is built on the assumption that there is a defined industry or sector. In this context related lead users can be identified, who are invited to co-create product concepts based on their needs (Henkel and Jung, 2009). LU embraces four major activities: identifying the trend, identifying lead users, analysing lead user data, and projecting lead user data into the general market of interest (von Hippel, 1986).

(2) Total System (TS) seeks to increase technology-push success rates by removing the main transfer barriers through the active involvement of the inventor along with the technical and commercial team. It recognises that a systematic combination of TS with pull strategies strengthens the method, e.g., prototype tests with consumers or free demonstrations (Souder, 1989).

(3) Probe & Learn Method (P&L) is based on the idea that there is a product embodying a new technology and that there is one or more markets to serve with its application. This is a technique in which the inventor tests early versions of the product in its potential markets with a cyclical learning and testing process consisting of three general stages: probing, learning and iteration. In each stage, the technology is adapted and improved according to the acquired information (Lynn et al, 1996).

(4) Roadmaps (RM) are utilised for handling large amounts of information about a given invention, which is in turn necessary to find a path for implementing the innovation. As a Graphical Modelling System (GMS), RM graphically depicts relationships between R&D and potential applications and functions as a tool for decision-making to find the best alternative (Zucher and Kostoff, 1997; Phaal et al., 2001).

(5) Market Brokering (MB) begins with an existing advanced technology or advanced stage prototype. In both cases, the aim is to find an application in the market under the assumption that it will add value to existing product lines in the marketplace (Lane, 2003). Even though many technological developments meet specific needs with new features and functions, the manufacturers often do not have detailed market information (e.g., market size, market segmentation and

penetration, etc.) or do not know how to obtain it (Bauer, 2003). This tool removes these marketing barriers by capturing the technology target through a flow of key information that enables a well-informed licensing decision (Leahy, 2003).

(6) Reverse Engineering (RE) has been considered a useful mechanism to transfer technical knowledge to machines or any advanced technology in its final development stage. The technical information is extracted by breaking down the product into its parts, for example, if the information about its planning and design is not available. With this knowledge, it is possible to use, maintain, or copy the technology. Thus, the technology can be reconstructed with similar characteristics as well as new specifications (Dehaghi and Goodarzi, 2011; Amini, 2017).

(7) Information Technology Platforms (ITP) serve as a tool for executing marketing activities at research organisations that seek to strengthen relations between the R&D sector and companies, allowing for optimal implementation of research results (Walasik, 2012). The functional activities supported by the technology transfer platforms are: disseminating scientific research results, horizontal activities (promotion, promotional products preparation supervision, product distribution), marketing activities, support in the process of International TT, brokering, building consortia, carrying out related projects, managing electronic tools supporting cooperation and evaluate innovative products (Walasik, 2018).

2.2 TRIZ Reverse: 7-Step-Approach

TRIZ Reverse is a reverse inventing method for knowledge and technology transfer, which is based on the Theory of Inventive Problem Solving (Eng. TIPS, Russ. TRIZ) developed by the Russian patent engineer Enrich Altshuller (1926-1998). It has recently been further advanced at the HTW Dresden in Germany.
As a result, the following systematic 7-Step-Approach could be derived:

› Step 1: Selection of a suitable invention (patent)

The initial step of the methodology is to conduct research on appropriate patents. The authors suggest using personal or professional contacts (network) with the objective of informing oneself about the relevant inventions available on the market. Another option to gather information is to contact universities, companies, or even private individuals, who are involved in the area of intellectual property creation or management.

› Step 2: Patent analysis and identification of relevant inventive principles

After a patent has been selected, the next step is to analyse the full patent text and to identify the most relevant inventive principles. This is to be done by finding technical parameters which are improved by the invention, and afterwards such ones are detected, which show a limit or lead to unwanted change.

The results must be then inserted into a tool based on the classic TRIZ contradiction matrix built for the acceleration of the inventive principle discovery procedure - the

inventive principle identification and prioritisation matrix (IPIP matrix) - which delivers the most likely results for relevant inventive principles.

› Step 3: Key word selection and search code creation

In this step, the identified inventive principles should be "translated" into the vocabulary used in the common language in patent texts, and thereafter a database search performed. For this purpose, the key word approach for assigning terms to the single inventive principles as proposed by Mann (2006) has to be applied.

› Step 4: Database research (search code testing)

The aim of step 4 is to identify the best matching patent hit lists by systematically testing the search codes created in step 3 in a patent database (e.g. dpma.de). The authors suggest looking for hit lists containing between 100 and 500 (+/-10) patents. A similar recommendation is provided by Glaser and Miecznik (2009) and Günther (2019).

› Step 5: Semi-automated patent list analysis

For the efficient analysis of the identified hit list, an automated IPC code identification matrix has been created with Excel. The matrix includes a systematic colour code scheme to facilitate the readability of the results. In order to take full advantage of the automation system, it is suggested to download the selected patent list (from the previous step) in ".xls" format, convert it to an ".xlsx"-file (newer Excel version format), and paste the identified patent list into the indicated cell and line of the file to ensure the best possible preliminary, semi-automated results of the patent analysis, including a visualisation of the distribution of patent clusters in various alternative application industries.

› Step 6: Manual patent list analysis (3 stages)

An in-depth manual analysis is performed on at least one of the selected IPC codes of second level hierarchy (e.g. H01). In this context, the IPC codes of second level hierarchy with the most occurrences are selected, and from there on the IPC codes of third level hierarchy (e.g. H01L) - with preferably five or more patents.

› Step 7: Discussion of possible cooperation and patent exploitation opportunities

The final step of the advanced TRIZ Reverse method is the presentation of the results to the client, which includes the discussion of any further steps of the technology transfer process. The authors suggest starting the presentation by revealing the most unexpected findings, which could be for example huge patent clusters in usually not connected areas of research. In conclusion, it should be noted that the decision for future executive steps in terms of cooperation or product development should not be made without careful consideration of the current market status or a market trend analysis.

2.3 Evaluation of TRIZ Reverse

Conceptual macro-areas or dimensions were defined to characterise the tools. Some of them were established by Weijo (1987) as the influencing factors for choosing a technology transfer strategy. However, additional customised dimensions were derived by extracting, analysing, and grouping key information from the literature. These are the dimensions considered for the comparison (Garzon/ Günther et al., 2021):

- Dimension 1 – Purpose: refers to the core aim of the tool.
- Dimension 2 – Market approach character: corresponds to the market-approach style and answers the question: 'Does the tool actively seek out market opportunities?' (Weijo, 1987).
- Dimension 3 – Stage of research and development: refers to the development point needed to initiate the TT, which answers the question: 'At which stages of development is it possible to use the tool? '.
- Dimension 4 – Structure of the distribution channel: related to the driver with which the tool operates and answers the question: 'Is the tool market-driven or technology-driven? '.
- Dimension 5 – Process shape: deals with the process type identified in the tool implementation and answers the question: 'Does the application of the tool fulfil its purpose with a single-use or are more cycles required?'.
- Dimension 6 – Market focus: related to the market-targeting goal and answers the question: 'Does the tool focus on a specific market?'.
- Dimension 7 – Agents' interaction: refers to the participation of own agents or third parties in the application and answers the question: 'Does the tool require (or makes necessary) the intervention of several actors in its implementation?'.
- Dimension 8 – Focus on communication: related to the existence of formal ways and channels of communication, which answers the questions: 'Does the tool require (or make necessary) two-way information transfer?', 'Does it promote a formal means of making communication constant?'.
- Dimension 9 – Knowledge requirements: refers to the technical skills required for the tool operation and answers the question: 'Is specialised knowledge required to apply the tool?'.
- Dimension 10 – Optimisation of resources orientation: corresponds to how the resource use is addressed and answers the questions: 'Does the tool use resources appropriately?', 'Is it based on cost reduction?'.

For an accurate visualization of results, a comparison matrix was constructed. The columns represent the tools, and the rows represent the dimensions. Their intersection takes a particular value according to the definitions of each dimension. The similarities with TRIZ Reverse are highlighted in dark blue (Figure 2). A total complete similarity is assumed for the dimension ‘purpose', although each tool necessarily differentiates from the others according to its relevant industry, market segment and users, (Garzon/ Günther et al., 2021).

No.	Dimension	TRIZ R	LU	TS	P&L	RM	MB	RE	ITP
1	Purpose & Goal	Transfer	Transfer	Transfer	Transfer	Transfer	Transfer	Transfer	Transfer
2	Market Approach	Active	Active	Active	Active	Active	Active	Passive	Passive
3	R&D Process	Late	Any	Middle	Middle	Any	Middle	Late	Any
4	Distribution Channel	Push	Pull	Mixed	Push	Mixed	Mixed	Push	Mixed
5	Process Shape	Mixed	Linear	Cyclic	Cyclic	Linear	Cyclic	Linear	Cyclic
6	Market Focus	Diverse	Focused	Diverse	Diverse	Diverse	Focused	Diverse	Diverse
7	Agents Interaction	Uniliteral	Interactive	Interactive	Interactive	Interactive	Interactive	Interactive	Interactive
8	Communication Focus	Informal	Formal	Formal	Informal	Mixed	Formal	Formal	Formal
9	Knowledge Requirements	Specific	Intuitive	Intuitive	Specific	Specific	Specific	Specific	Intuitive
10	Ressources Optimization	Optimizer	Optimizer	Optimizer	Dispenser	Optimizer	Optimizer	Dispenser	Optimizer

Fig. 2: Comparison Matrix of Technology Transfer Tools (Garzon/ Günther et al., 2021)

3 TRIZ Reverse Application: Case Studies

The following chapter will provide an overview of two in depth patent analysis case studies with the support of the TRIZ Reverse methodology developed at the HTWD. In this regard, it is important to mention that the first case study concerns an invention with a technology readiness level (TRL) of 3, meaning that a proof of concept was demonstrated by the patent holders. On the other hand, the invention in the second case study should be categorised in the range of a TRL of 1 (basic research), meaning that this technology is at the very beginning of its developmental cycle.

3.1 Collagen-based Layer Material (CBLM)

3.1.1 Introduction to Inventive Solution

To develop the TRIZ Reverse methodology and identify alternative application fields of an already protected technology, an HTW Dresden owned patent (Harre et al., 2019) in the area of medicine (IPC main class: A61L 27/44) has been selected.

The full title of the patent is ‘Biocompatible molded part and process for the production of a collagen-based layer material’. A simplified illustration of the process (patent code DE102017123891) can be seen in Figure 3.

A short fragment of the patent text provides a brief understanding of the new technology: ‘A method for providing a collagen-based layer material (3), comprising the following steps: - providing at least one swellable collagen material (1), - contacting the swellable collagen material (1) with an aqueous solution so that the swellable collagen material (1) can swell, arranging the swollen collagen material (1) in layers so that a layer arrangement (2) with at least two layers (1.1 to 1.5) lying on top of one another at least in some areas is formed, and air-drying the layer arrangement (2) at a temperature below 50 ° C, whereby the superficially adjacent layers (1.1 to 1.5) are crosslinked with one another.’ (Harre et al., 2019: 1).

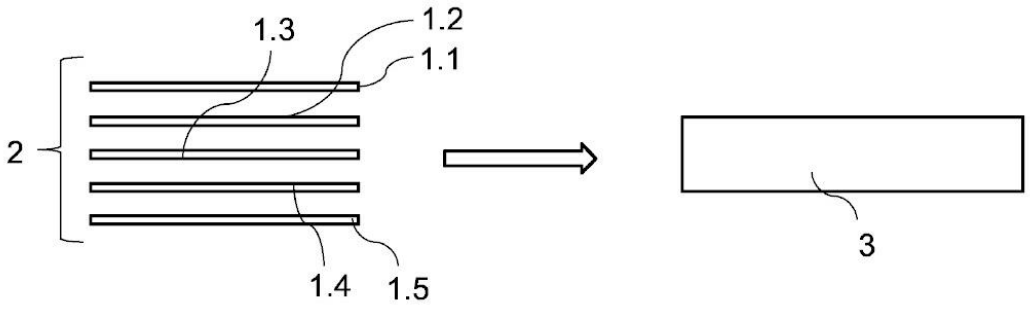

Fig. 3: Patent DE102017123891 (invention 1) (Harre et al., 2019)

3.1.2 Potential Fields of Application

The case study CBLM (based on patent DE102017123891) performed using the TRIZ Reverse method for systematic invention as well as knowledge and technology transfer has revealed a multitude of unexpected alternative areas of potential business ventures. One of the biggest surprises was the occurrence of huge patent clusters – hence possible business development opportunities - in the industries of semiconductors (H01L), construction (E04B) and container/storage/transport (B65D). Even though the identified results are promising, the authors’ opinion is that there is still work to be done until first tangible evidence can be provided in terms of successful product development and large-scale entry of at least one desired target market. When it comes to the process itself, the group has achieved a remarkable increase in the degree of automation of the analysis procedure of relevant patent texts. Nevertheless, the research team aims to further increase the efficiency, data recognition and handling accuracy of the tools utilised.

Given the recent results and findings of the patent analysis performed, the decision has been made to actively pursue diverse options of accelerating the process of product development and market entry in the packaging industry. Thanks to funding acquired from the state of Saxony and the SAB (Development Bank of Saxony), the patented collagen-based layer material is currently being prepared for exploitation within the project validation funding (Validierungsförderung). In the context of this project,

industrial cooperation with corporations (e.g. Procter & Gamble) and several regional SMEs are currently being sought. First successes can already be noted, in that the acquisition of a follow-up project with one of Fraunhofer's institutes was achieved in the past few weeks. In addition, current research results were presented in various innovation and technology presentation events for the purposes of networking and project result documentation, such as the recent meeting of the Industrial Association Saxony (Industrieverein Sachsen 1828 e.V.). Furthermore, the examination of further patent protection options is being planned with the support of a patent law firm.

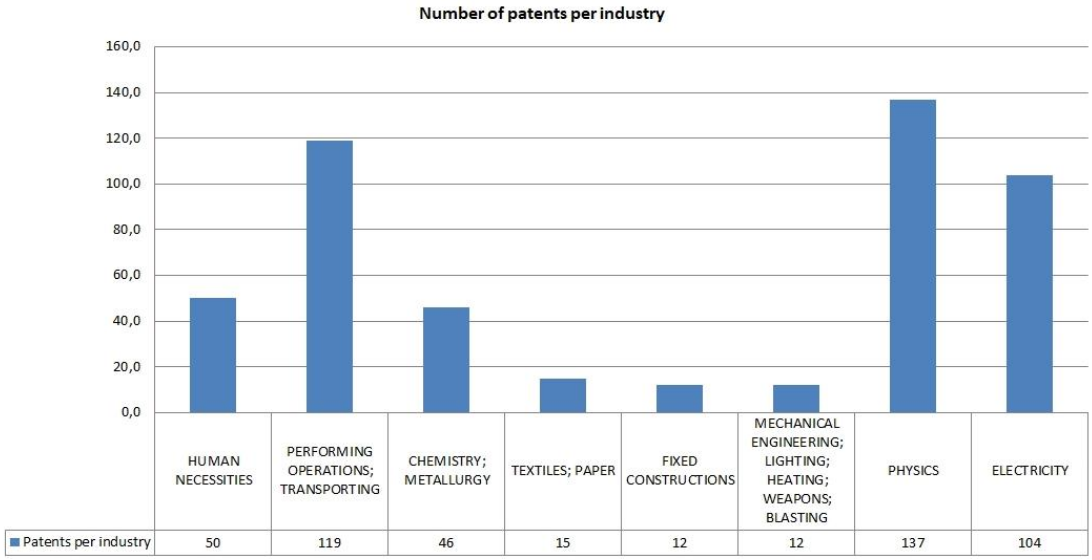

Fig. 4: Semi-automated analysis tool –industry distribution of hit list results from step 5

3.2 Self-Synchronizable Network (SSN)

3.2.1 Introduction to Inventive Solution

In order to test and improve the TRIZ Reverse method, a case study patent analysis has been performed with the aim of alternative technology application field identification. The patent under observation is co-owned by the Max Planck Society (Germany) and the Technical University Dresden (TU Dresden, Germany) (Wetzel, L. et al., 2019). The relevant IPC class is G06F 1/12, which refers to inventions in the field of electrical digital data processing, in particular to the synchronisation of various clock signals. The full title of the patent is 'Self-synchronizable network'. Figure 5 demonstrates a simplified illustration of the decentralised system approach (non-hierarchical structure) used in patent US10241539B2, in order to achieve synchronisation in networks of mutually delay-coupled oscillators.

The following text fragment (patent summary) provides a brief overview of the technology: 'A solution for synchronizing a network comprising a plurality of interconnected nodes provides a stable synchronized state, especially for large scale networks. Signal transmission speed and the length of each interconnection of the network is configured to cause a delay of the signals received by a node from the other node of the

interconnection which is larger than one millionth of the free-running period of the controllable oscillator of the receiving node such that Network-wide synchronization of oscillators is achieved for all nodes of the network in a continuous self-organized process in interaction with the other node of the network' (Wetzel, L. et al., 2019).

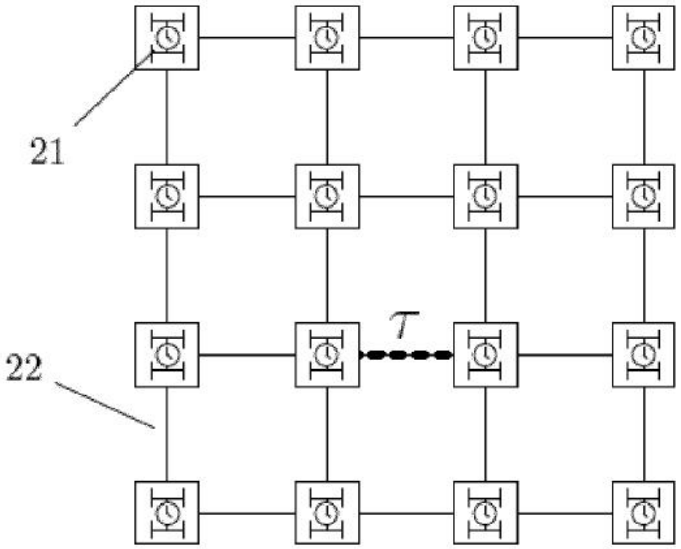

Fig. 5: 'Self-synchronizable network' – illustration from the patent (Wetzel, L. et al., 2019)

3.2.2 Potential Fields of Application

The results of the case study SSN (US10241539B2) have offered insights into several potential areas of alternative industry technology application. Regarding the biggest patent clusters (represented by the most prominent IPC classes or industries), some unexpected results became clear, e.g. a large cluster in the human necessities sector (IPC=A), particularly in the field of medicine or veterinary medicine and hygiene (A61).

Apart from that, expectations from the patent owners in regard to alternative industries of application were confirmed, in that e.g. a huge patent cluster was discovered in the sector of performing operations and transporting (IPC=B), especially in the field of general vehicles (B60). Other very large clusters have been identified in the physics (IPC=G) and electricity (IPC=H) sectors, which did not represent an unexpected outcome of the analysis. Figure 6 demonstrates the results of the semi-automated patent analysis using TRIZ Reverse and its tools in the case study SSN.

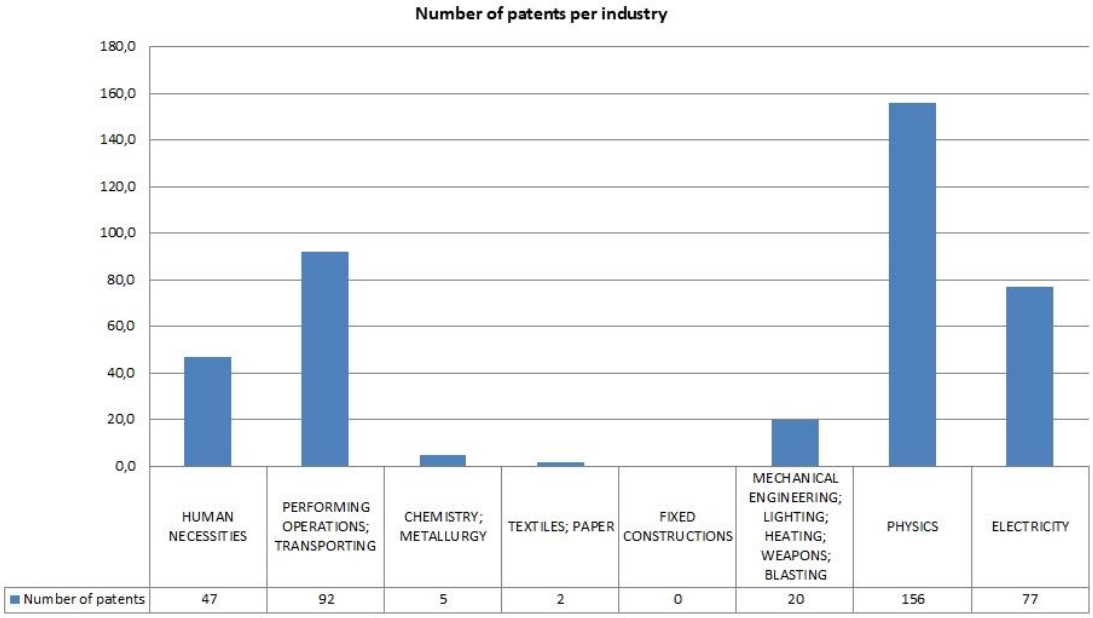

Fig. 6: Results of the semi-automated analysis – Case study 'Self-synchronizable network'

An in-depth analysis of the patent in the sixth step of the TRIZ Reverse method revealed the largest relevant patent clusters in the following industries:

› B41J - typewriters; selective printing mechanisms, i.e., mechanisms printing otherwise than from a fore; correction of typographical errors

› G01N - investigating or analysing materials by determining their chemical or physical properties

› A61B - diagnosis; surgery; identification

› G01S - radio direction-finding; radio navigation; determining distance or velocity by use of radio waves; locating or presence-detecting by use of the reflection or re-radiation of radio waves; analogous arrangements using other waves

› G06F - electric digital data processing

Currently, the relevance of the identified patent clusters is being assessed together with the patent owners. Furthermore, information is being accumulated on the market entry opportunities by acquiring an overview of the existing market gaps, which could be "closed" by an application of the patented technology. In comparison to the previously discussed patent analysis, this one can be described as generally more challenging due to the involvement of fundamentally new knowledge in the field of basic research (i.e. the low TRL level of the invention).

4 Conclusion and Outlook

The authors highly recommend TRIZ Reverse as a tool in transfer departments of universities and research institutes. It offers great potential for a systematic approach regarding the task of knowledge and technology transfer in any department. Thus, it addresses one of the major bottlenecks of the innovation process: the exploitation and utilisation of patents as a common outcome of research processes. According to empirical findings, the vast majority of patents are ultimately put on hold and are never used or implemented in practice. Frequently, the wrong field of application is targeted. At the same time, alternative, and sometimes even more suitable fields are ignored, or not recognised by researchers – at least not soon enough. The result amounts to missed opportunities for profit.

To resolve this problem, transfer managers or consultants are usually hired with the aim to provide their (individual) expertise and knowledge in order to find potential customers and companies. Nevertheless, the efficiency of such an approach is limited due to lack of methods and/or knowledge, available networks and/or psychological inertia of experts. Therefore, a standardised tool like TRIZ Reverse should be urgently implemented in knowledge and technology transfer departments of universities and other research organisations. This would significantly support the process of searching for relevant markets and fields of application for new technologies.

Looking at the most time-consuming parts of the patent analysis itself, the greatest potential for time reduction lies in the first part of the patent text analysis step (step 2). Therefore, a solution which could speed up the recognition of the relevant technical parameters, e.g., a software program for text mining using artificial intelligence (AI), should be incorporated in the set of TRIZ Reverse analysis tools. For this reason, the project team is currently searching for potential partners and research institutes that are specialised in programming and text mining.

Nevertheless, the discovery has been made that this knowledge and technology transfer tool can only gain the attention it deserves, if the application of the single steps becomes more user-friendly. For this purpose, funding for a transfer project has already been requested and approved by the Federal Ministry of Saxony SMWK in order to develop a semi-automated software solution. This digital application will provide support in the process of patent exploitation to technology transfer coordinators, patent analysts, and all people involved in the domain of innovation.

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USC Ecosystem: A comprehensive framework for University-society Co-Creation

Kerstin Kurzhals[1]; Annika Wesbuer[1]; Katrin Uude[1]

1 FH Münster University of applied sciences; Münster school of business

Abstract

Rising complexity in today's society is causing rising social challenges that can be solved through interdisciplinary partnerships, networks and socio-technical solutions (Brandt et al., 2019). Higher education institutions (HEIs) are expected to assume greater societal responsibility. Consequently, HEIs are increasingly taking on these social challenges as the "Third Mission " (TM) besides teaching and research (Olo et al., 2021). As a part of this mission, university-society co-creation (USC) with social actors (e.g. non-profit organisations, NGOs) are targeted (Compagnucci, Spigarelli, 2020; Berghäuser et al., 2019). This paper intends to help successfully strengthen co-creation influenced by diverse conditions and co-creation factors. Therefore, this paper aims to fill the research gap by translating determined parameters from literature to the USC framework for HEI managers and societal partners. The literature builds on relevant and preliminary research in this area, such as "The university-business co-creation (UBC framework)" (Galan Muros, 2015), "Academic Engagement Framework" (Perkmann et al., 2021), and "Co-delivery of social innovation" (McKelvey & Zaring, 2018). However, co-creation success differs in dependency on the co-creation goals and types (Baaken, 2019) and whether the parties overcome obstacles and are willing to follow organisational norms (Plewa, 2009). Thus, the USC framework is intended to support strategic and operational decision-making by guiding the requirements for successful co-creation.

Keywords

University-Society Co-Creation; Framework; Management; Social innovation

1 Introduction

Co-creation with different stakeholders has become an essential part of the higher education institution (HEI) activity (Bischoff et al., 2017). Defined as a 'joint action for mutual benefit' (Dugatkin et al., 1992), co-creation increases competition for innovation and growth (Baaken, 2019). Advantages of co-creation show mutual knowledge transfer that can tackle society's current and future challenges (Healy, 2012). Hence, one solution for these upcoming problems is HEI's Third Mission (TM) taking over their responsibility through university-society co-creation (USC). The current research focuses on barriers, drivers, and co-creation factors for co-creation between HEIs and their business partners (Galan-Muros, 2018). However, co-creation success differs in dependency on the co-creation goals and types (Baaken, 2019). Hence, in the case of co-creation between higher

education institutions and societal actors, this study focuses on the individual co-creation factors between higher education institutions and society.

Considering the increasing importance of co-creation, this study will examine the joint work between higher education institutions and social actors. While current research is limited to the wide range of higher education with businesses, different emerging conditions need to be considered depending on the partner and co-creation type (Baaken, 2019). Galan-Muros' research focuses mainly on the influential co-creation factors for successful HEI co-creation with business partners. In this context, all elements arise from the win-win perspective. For example, companies receive well-trained students from the co-creation, knowledge exchange is made possible, and R & D research jointly with companies is possible (Galan-Muros, 2018). Given the co-creation intentions with societal actors, a social goal is in the foreground.

Thus, more research is needed to understand the critical co-creation factors for successful co-creation between social actors and higher education institutions. This research focuses on a previously underrepresented area of study to strengthen the co-creation for both parties. In particular, the influential co-creation factors need to be determined and identified to what extent they differ from those already identified in the higher education business ecosystem (Prantl et al., 2021). This perspective is particularly important for higher education managers, practitioners, and academics targeting the TM and the associated social innovation (Păunescu et al., 2022). In addition, it is crucial to learn how co-creation factors influence this co-creation process in that stakeholders can be alert to obstacles and actively address drivers. To achieve these objectives, the following questions will be addressed:

(8) What are the influencing co-creation factors for co-creation projects between HEIs and society partners?

(9) How do the influencing co-creation factors of projects between HEIs and society partners affect the project?

In examining higher education co-creation, we apply the literature on university-business (UB) co-creation (Galan Muros, 2019) and the relevant literature streams for co-creation factors (Academic Engagement Framework (Perkmann et al., 2021); Co-delivery of social innovation (McKelvey & Zaring 2018). The basis for the study's development is Galan-Muros' UBC Ecosystem Framework, which lists various co-creation factors that influence co-creation. Based on this literature, this study contributes in several ways. First, it expands the information on the higher education cooperation and allows for further higher education strategic opportunities outside of UBC. Secondly, the co-creation factors are listed and further completed with the experiences of academics from the co-creation projects.

The paper is structured as follows. First, the literature review gives an overview of the meaning of Third Mission, social innovation, and university co-creations and its ecosystem, from which the theoretical framework according to Galan-Muros' model is

derived. To verify the literature-based co-creation factors and the Galan-Muros model as a reference utility, the quantitative pre-study followed by a focus group is then described. The results are then presented and illustrated, corresponding to and deviating from the literature-based co-creation factors and the Galan-Muros model. The results then list and discuss the most influential co-creation factors and their significance for US co-creation. Implications for social actors who can assess the immediate success of increasing quality of life are highlighted (McKelvey et al., 2017). At the same time, social actors are the ones who must demonstrate a willingness to engage in this co-creation. A discussion of limitations and future research directions concludes the paper.

2 Theoretical Background

With the increasing responsibility of higher education institutions (HEIs) and the aim to fulfil the Third Mission, scholars look out a rising co-creation between HEIs and social actors. One of the most important reasons why social actors (e.g. Non-Governmental Organisation (NGOs)) and HEIs should cooperate is the common goal of advancing education and identity development in society (Hartsmar et al., 2008). Co-creation can help NGOs communicate current life challenges, while HEIs contribute to solution support through their theoretical frameworks (Tryma & Salnikova, 2020). Another potential opportunity for such co-creation is mutual learning between HEIs and social actors (Balbachevsky et al., 2020). However, only co-creation between HEIs and corporate partners has been studied so far regarding the different co-creation factors that can influence this co-creation process.

Until now, there are no theoretical approaches in the current literature that investigate and describe co-creation factors in the context of TM and social innovation. For this research, we apply a theoretical framework (Galan-Muros, 2019) based on the interaction between HEIs and social actors. Furthermore, we assume that these co-creations have different characteristics and multiple co-creation factors than co-creations with corporate partners. Building on the previously mentioned objective, the following section introduces the Third Mission, Social Innovation, the university ecosystem, and the UBC Ecosystem Framework.

2.1 Third Mission

Increasing global challenges and constant technological achievements cause life to become more complex and lead to social and economic shifts for which new solutions must be found (Morawska-Jancelewicz, 2021). In this context, HEIs are expected to contribute to transformative socio-economic change beyond their traditional missions (Kesting et al., 2018) by producing human, social and entrepreneurial capital (Guerrero et al., 2015). HEIs are increasingly confronted with the task of using the results of their first mission, teaching, as well as their second mission, research, to find solutions to the growing challenges faced by societies and local communities (Correia & Rego, 2021).

This obligation is referred to as the Third Mission (TM) of HEIs (Brandt et al., 2018). In the third term, the task can be considered a complex, evolving phenomenon (Compagnucci & Spigarelli, 2020). In their definition, Schoen et al., 2007 refer to the TM as relationships with non-academic stakeholders, especially corporations, the government, and society, for the benefit of knowledge sharing and productive co-creation. Accordingly, the TM encompasses all activities related to the generation, use, application, and exploitation of HEIs knowledge, skills, and resources outside the academic environment (Roessler & Hachmeister, 2021) to contribute to global social, cultural, and economic progress (La Torre et al., 2017). However, the TM is not to be understood as a one-size-fits-all approach but varies from HEI to HEI (Compagnucci & Spigarelli, 2020). Hence, the "Third Mission "has also been discussed as the second academic revolution (Etzkowitz, 2003), which has caused a shift away from the traditional ivory tower attitude of HEIs that previously thought of research and teaching solely as purposes in themselves (Nakwa & Zawdie, 2016). The "Third Mission "finds its origin in the 1980s (Roessler & Hachmeister, 2021), emanating from US universities that increased their entrepreneurial activities to contribute toward the societal common good through pressure from governments and corporations to deliver a return on investment (Guerrero et al., 2015). Nevertheless, interactions and contacts with society progressively included other groups besides companies (Benneworth et al., 2009). Today, HEIs have established themselves globally as critical players in cultural and economic growth (Svensson et al., 2012).

2.2 Social Innovation

A frequently referenced approach to a unified definition in the literature was developed by J. A. Phills Jr, K. Deiglmeier and D. T. Miller in 2008: "[Social innovation is] a novel solution to a social problem that is more effective, efficient, sustainable, or just than existing solutions and for which the value created accrues primarily to society as a whole rather than private individuals. In addition, social innovation is increasingly regarded less as a solid scientific concept, but instead used unreflectively as a buzzword in the current political and lay discourse (McSweeney, 2020). Due to the high diversity of different fields M. Nyssens posit in their literature review "the impossibility of a unified definition" (Defourny & Nyssens, 2017).

2.3 Co-creation in the university ecosystem

Since the mid-1900s, the co-creation between higher education institutions (HEIs) and external public and private organisations has steadily increased (Davey et al., 2011; OECD). Initially caused by pressure on HEIs to generate a return on the investments they receive (Breznitz & Feldman, 2012), they are today widely acknowledged as one of the most important sources of innovation in terms of economic and social development (Clarysse et al., 2011). In this course, the literature also refers to university-business co-creation (UBC) to generate mutual benefits (Galan-Muros & Davey, 2019) or the term "entrepreneurial universities" (Stolze & Sailer, 2021). The spiral model, known as Triple

Helix, has been established as a standard for describing this collaborative form of capitalisation of knowledge. It follows the idea that innovation results from an interactive process, in the form of joint participation of the three actors, according to their "institutional" function in society (Henry, 2015). Hence, the idea of a "network model of innovation", also referred to as a "techno-economic network", was introduced (Laredo & Mustar, 1996). According to Jacobides et al., such an ecosystem is characterised as an interplay of organisations that are not hierarchically managed but connected by the fact that their collective investments cannot be redeployed elsewhere. Co-creation is thus the decisive component and basis of value creation for all actors involved, which depends on respective commitment and behaviour, according to the "mutual self-interest" (Tönnissen et al., 2020). The literature also refers to this as "co-innovation", according to which the actors of a network can only encounter the dynamic changes of the global market and the associated intense competition by collectively generating value (Lee et al., 2012).

2.4 University-Business Cooperation Ecosystem Framework

The UBC ecosystem as an integrative framework allows to understand the complexity of the UBC phenomenon (Galan-Muros, 2017). The UBC ecosystem framework, according to Galan-Muros, 2019 includes the UBC process, UBC support mechanisms, UBC circumstances and UBC context. The UBC process is based on the Logic Model, a graphical assessment tool. The Logic Model is used, for example, in programme planning and implementation. Furthermore, the purpose of the process is to describe how interventions work, how they can achieve goals and influence behaviour (Kneale et al., 2015). According to the Logic Model (Kellogg, 2004), the UBC process includes UBC input, defined as the key to successful UBC (Das & Teng, 2000). It consists of all resources used in the UBC process and finds its use in the activity part. For example, human resources with the various HEI target groups and their evolved benefits in a UBC are part of the input factor. In addition to the input factor, the factor "activity" describes how knowledge transfer occurs (Kitagawa & Lightowler 2013). The third factor of the UBC process includes three subcategories. "Output", "outcome", and "impact" are the three UBC results. In other words, this distinction is necessary to justify government funding in detail and outline which areas it affects (Piva & Rossi-Lamastra 2013). Output is a direct result of UBC activity. This subcategory of the outcome can produce different results depending on the audience. For example, academics may receive new publications, business partners obtain new products and the higher education institution benefits from new approaches. The second outcome subcategory includes direct use for all stakeholders of UBCs (van der Sijde, 2012). This statement does not exclude that these can be positive or negative for the actors. In contrast to 'outcome', 'impact' describes the indirectly experienced results. The penultimate of the UBCs is the support mechanism. This factor helps manage the UBC to provide adequate conditions and achieve positive impacts. Finally, UBC circumstances examine the temporary internal and external influencing co-creation factors that management actions can change (Galan-Muros, 2019).

3 Methodology

3.1 Research context

This paper focuses on co-creation partnerships between researchers from higher education institutions from different disciplines and social actors to develop positive outputs for society. As TM emphasises co-creation, the essence of this co-creation is a benefit for the community (McSweeney, 2020). Hence co-creation on this level allows a deeper understanding of influencing co-creation factors. For this purpose, data was collected with the help of a questionnaire in which literature-based co-creation factors of scientists from German US co-creations had to rate them based on a Likert scale from 1 (strongly disagree) to 5 (strongly agree). Followed by two parallel focus group, analysed based on the Mayring content analysis with the four-stage co-creation model. The focus group participants belonged to the “münster.land.leben” project. A project of Münster University of Applied Sciences, which deals with the major social challenges together with many stakeholders. The aim of the project is to promote health, participation and well-being in rural areas. Before the focus group started, all participants were prepared for the research question in advance in the form of a presentation of the four-stage co-creation model. Afterwards, the moderator presented the rated co-creation factors in the interactive, digital Miro Board. This preparation time enabled the focus group members to remember the aspects and the experiences of their co-creation (Flick, 2002). The researchers introduced the selected elements and their importance and then filled in with the participants' experiences in the plenum. Emerging and complementary co-creation factors were discussed, in which the members set the focus on the parts.

3.2 Research Design

A deductive approach sets the frame of this research to transfer the university-business co-creation framework to university-society co-creation. For this transfer, a case study approach was conducted to explain the findings from the pre-study questionnaire. Using a quantitative method based on an online survey and the arithmetic mean of the research-based co-creation factors, the predominant conditions in USCs are determined numerically. Consequently, we used measurement scales in conducting online surveys to assess the relevance and a pattern of various co-creation factors for USC (Lakshman, 2000). To generate cost-saving data, a focus group was conducted after the quantitative pre-study (Lakshman, 2000). The heterogeneous focus group with HEI members from different hierarchies allowed a dynamic interaction between all actors to get additional accounts of their experiences (Tausch & Menold, 2012). Focus groups provide the opportunity to generate and understand the attitudes and decision-making approaches of the quantitative results through more open and honest communication between the participants (Wilkinson, 1998; Bartle, 2003). In two parallel focus groups, seven participants from the "münsterl.land.leben" project discussed their co-creation experiences. This discussion offered profound and more diverse insights into the influences of

the identified co-creation factors (Doody et al., 2013). Focus group facilitators asked semi-structured questions for one hour to explore and lead to specific experiences received in the USC context (Fitzpatrick & Mayer, 2020). The semi-structured questions create a situation where the participants communicate and discuss more with the other focus group members than with the researchers themselves (Wilkinson, 1998; Onwuegbuzie et al., 2009).

3.3 Sample

Online surveys created with Qualitrics were distributed to academic members at German HEI to obtain empirical data. These institutional members work in the context of a TM and achieve SI with their social project partners (e.g. NGOs). As a result, these faculty members can report on their collaborative experiences on at least six months of collaborative work that they are currently still experiencing in a project or have experienced in the past. These collaborating members were found via German universities' TM websites and contacted personally via mail. In total, 48 questionnaires were completed out of 200 emails sent. Respondents were assured of anonymity, and it was made clear that there would be no right or wrong answers (Podsakoff et al., 2003). A total of eight responses had to be removed from the data collection due to incomplete responses and early termination of the survey. These survey results lead to a final sample of 40 responses and a response rate of 0,2. The data obtained contained information about the demographic profile of the sample. Here, the sample consisted of 52 per cent men and 47 per cent women with an age distribution of (20-29, 20.5 per cent; 30-39, 29.4 per cent; 40-49, 20.5 per cent; 50-59, 17 per cent; 60-69, 11.7 per cent). More than 48 % of the respondents had a master's degree or even a doctorate. 55.5 per cent of the sample were part of the "münster.land.Leben" project, which includes more than 75 societal organisations and aimed developing health, participation and wellbeing in the rural area of Münsterland. Following the quantitative pre-study, focus group members working in the "münsterl.land.leben" project for at least two years were invited via mail. These research associates hold different hierarchical positions and have encountered various social co-creation partners. Furthermore, these focus group members had diverse fields of responsibility within the US co-creation. This heterogeneous composition of focus group members assessed the four levels of the co-creation model, as some co-creation factors are position-bound. Seven people participated in two parallel focus groups, led by one and two researchers, respectively, through the qualitative approach (Doody et al., 2013).

3.4 Research instruments & Data analysis

The focus group was recorded with audio and video and then transcribed. After transcription, deductive coding according to Mayring took place. This was followed by a specification of the research question, followed by the definition of the unit of analysis. The previously defined coding guide led a direct transition to the deductive category

application. Codes were defined on the basis of Mayring's content analysis and the four-level UBC model (Mayring, 2003; Wilkinson, 1998; Morgan, 1998). Sub-codes were developed on this basis. These were recognisable as patterns for identifying and analysing topic patterns with MAXQDA (Carson et al., 2001). We assigned content to each factor step by step. In order to avoid different perspectives and bias from the two parallel focus groups, the participating researcher conducted the analysis (Denzin, 1989). A reflection phase according to Mayring, 2008 was inserted after 10 to 50 % of the coding had been done. After the reflection, the rest was coded. This was followed by a reality check with both coders. Finally, the frequency of the respective statements was compared with each other, resulting in the quotations in the following tables. We then compared the formulated themes and characteristics with the existing literature and mapped the quotes from each focus group member to the co-creation factors.

3.5 Results

In line with the mentioned research questions, we first present the co-creation factors influencing the co-creation process between higher education institutions and social actors. In support of these findings, we offer the focus group testimonies on the influence of these co-creation factors on USC. We have identified co-creation factors and their impact on the USC process (c. Figure 1). Of course, co-creation factors in US co-creation may differ in dependency of the regionality from the co-creation factors listed below.

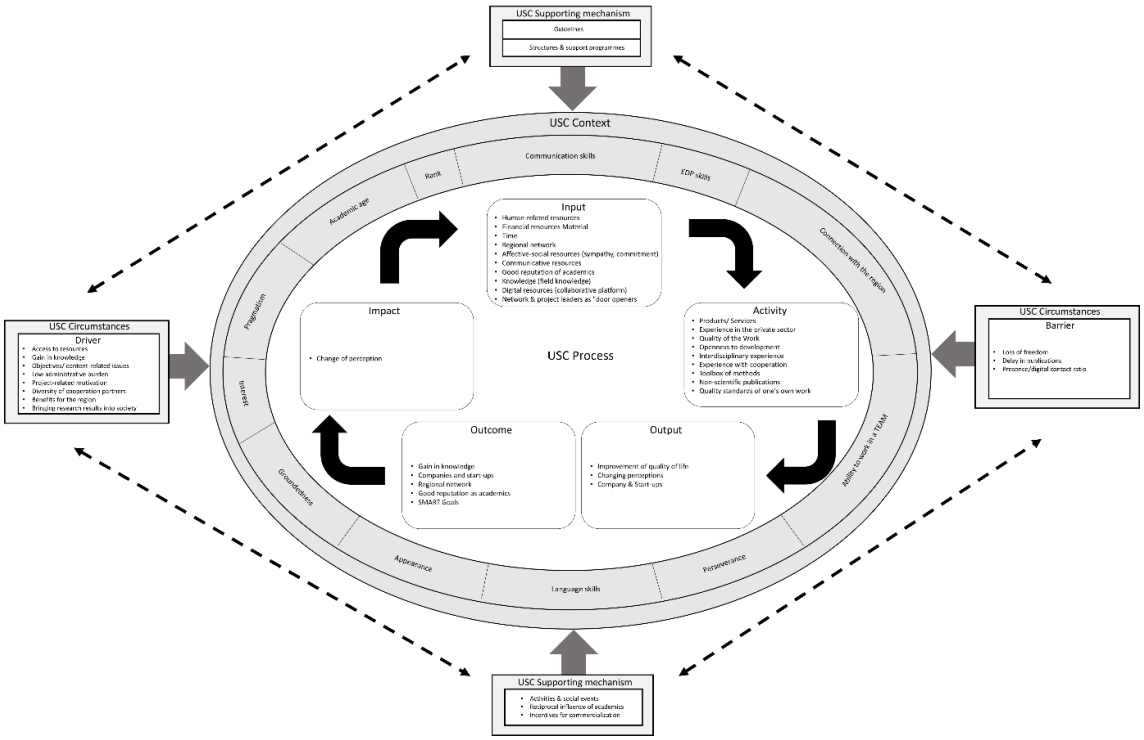

Figure 1 Co-creation factors influencing university-social co-creation.

3.6 USC Process

This study confirms the USC Process and the co-creation factors based on UB Co-creation (Galan-Muros,2019), according to the influencing co-creation factors of the Logic model identified by the respondents.

Input

Human-related resources

One factor that respondents rated as necessary is "input". Sub-co-creation factors include human-related resources, in which respondents rated diverse teams with a sensitive approach as essential. According to the respondents, this sensitive approach was crucial due to citizens' negative experiences and prejudices when academics approach citizens and social actors. During the focus group, participants described overcoming these prejudices by meeting social co-creation partners at an equal level (c. table 1). Moreover, meet open-mindedness through academics' diverse professional experience, like the citizen's qualification "When I (…) mentioned that I used to work in nursing, then I had an easier connection with people if they had similar training." (Person 2, Focusgroup 2, No.2021)

Financial resources

Apart from human-related resources, financial resources are also relevant for US co-creation. Respondents have indicated that the duration and financial requirements were insufficient for long-term impact in the process part "activity". In other words, there would not be a long-term success for the society's well-being if adequate funding was not made available over the regular three years of funding (c. table 1). Thus, the actual goal of social innovation, to address complex social challenges (Pol et al., 2009), cannot succeed with these co-creations, as "the difficulty at the moment is that (…) the funding policy (...) supports many projects, but they always only run for three years. It's thought that you have to have achieved an effect this time. Unfortunately, that is not the case. Long-lasting funds are needed to make an impact." (Person 5, Focusgroup 1, No.2021).

Time as a resource

"There were three years of funding. That means (…) we had fortunately created a basis. So, we didn't have the situation whereby some people thought about us, that the HEI come and want to carry out a short project that is then over again and the citizens have nothing to gain from it." (Person 3, Focusgroup 1, No.2021). The interviewees described the importance of having enough time as a resource for the follow-up activity. Thus, the social actor's prejudices are reduced over enough time (c. table 1). These decreased prejudices set the link to the importance of investing knowledge, time, skills, and effort into a relationship (Galan-Muros; Davey 2017). Furthermore, Tönnissen et al. 2020 emphasise that effective ecosystem design and investing time in a relationship builds trust (Selander et al., 2010). These were precisely the experiences the respondents reported and highlighted that, especially in the introductory phase, academics need more time to reduce social actors'/society's scepticism and build trust to benefit from the co-creation.

Regional network

The regional network develops over time and allows current networks to expand (Lee & Bozeman, 2005) as co-creation attitudes and behaviours change through co-creation experiences (D'Este and Patel, 2007). Indeed, the HEI's expertise in co-creation and an existing network can act as a door opener for further co-creation (Galan-Muros; Davey, 2017). Exceptionally experienced researchers have a distinct network, considered social capital. That has the advantage of providing many potential partners willing to cooperate (Giuliani et al., 2010; Haeussler and Colyvas, 2011; Landry et al., 2006). The interviewees reported corresponding experiences in that they could fall back on the established networks (c. table 1). Moreover, the interviewees said that it became practical to "include (…) the local NGOs because we would like to reach the bigger communities" (Person 2, Focusgroup 2, No.2021) to have an easier connection to society in an unfamiliar region.

Affective-social resource

Successful partnerships are the base for stable interpersonal relationships that develop a common interest in tackling challenging tasks (Al-Youbi et al., 2020). Overcoming complex tasks creates a sense of community. Before that feeling can arise, affective-social resources are essential. For this, open communication (Schmidt & Schönheim, 2021) at an equal level (…) and a typical understanding and empathy" (Person 2, Focusgroup 1, No.2021) should be present.

Appearance of academic

According to Perkmann et al., 2013, academics with higher rank and high social capital are more likely to enter into co-creation, attributed to their experience (Giuliani et al., 2010). In the US co-creations, however, the academics reported that the prerequisite for a successful co-creation is a positive appearance in the academics (c. table 1). The appearance acts as a door opener for co-creation in the social context. Furthermore, the focus group participants stated that an excellent academic reputation is a key and the regional connection and familiarity as a person.

Knowledge

A common goal and interest for both the transfer holder and the transfer provider are crucial for co-creation (Schmidt & Schönheim, 2021). The academics emphasised that "when I mentioned that I used to work in care, I had an easier connection to people" (Person 2, Focusgroup 1, No.2021). According to the focus group members, a sense of community emerged as soon as a common field of expertise arose, e.g. a similar previous education (c. table 1).

Digital resources

"It is essential to have the digital connection with each department because each department wants to reach more audiences (…)" (Person 1, Focusgroup 1, No.2021). This statement points out the evaluation of the digital resources, which was considered essential in the US co-creation. Academics reached a larger audience with digital

resources (c. table 1). Furthermore, this technology offers the potential for internet-based co-creation, in which co-creation can form a common knowledge and joint action (Al-Youbi et al., 2020). Significantly, the pandemic situation showed the necessity and efficiency of this technology, as it allowed initial face-to-face meetings to take place online (Olo et al., 2021).

Table 1 The USC defined factor "input" by academics from the quantitative study and focus group

	Quantitatively pre-determined co-creation factors		***Quotes from the focus group***
Factor category	**literature-based factors**	***Factors based on academics' experience***	
Input	*Personal resources*		"a diverse team (...) staffing with different competencies that have (…) background knowledge can sometimes also succeed in the same way and then someone with more experience (…). Independence in such projects, I don't need to tell them much more because many things are already there." (*Person 1, Focusgroup 4, No.2021)*
	Material resources		
	Financial resources		
		Time	*"The projects run longer because these are all things that start at a particular place (…), but certain things need time because you can't change a calculation overnight (…), but attitudes and behaviour change need this time. This time is often not given." (Person 1, Focusgroup 1, No.2021)* *"That means not having a lot of time in the beginning, (…) to practically understand each other's language from the contexts etc. and then to work towards a common set of values, goals" (Person 2, Focusgroup 2, No.2021)*
		Regional network	*"Because "regesBOR" stands for Borken, we had the regionality, and that is perhaps also a bit of benefit for such (…) anchored networks. (…) You have a region that you already got to know (…)Whenever regesBOR was on the list and was already a bit known, we had no longer the experience of somehow being seen as an ivory tower. (Person 1, Focusgroup 2, No.2021)* *"At the moment when we approached citizens, we always appeared together with the network, and of course it was great." (Person 1, Focusgroup 2, No.2021)*
		Affective-social resources	*"Having a normal understanding and empathy with and for things that practically came up." (Person 1, Focusgroup 1, No.2021)* *"To be at eye level with the citizens on the spot, that this is a very central point." (Person 6, Focusgroup 1, No.2021)*
		Communicative resources	*"But we succeeded very well by carefully acting in the sense of empathetic communication, in other words, always remaining at eye level, but this project leader, scientist as door opener". ((Person 2, Focusgroup 3, No.2021)*
		The good reputation of academics	*"No, not entirely because of my academic reputation, but because of my regional ties (Person 1, Focusgroup 2, No.2021)*
		Knowledge	*"When I mentioned that I used to work in care, then I got an easier connection with the people who also do similar work." (Person 2, Focusgroup 1, No.2021)*
		Digital resources	*"It´s essential to have the digital connection with every department because every department would like to go reach more audiences (Person 1, Focusgroup 1, No.2021)*
		Network & project leaders as "door openers	

Activity

Interdisciplinary experience

The importance of clear communication and the exchange of existing prior knowledge for conflict-free co-creation (Schmidt & Schönheim, 2021) was demonstrated in the US co-creation by the diverse professional groups and settings involved. In this context, academics need interdisciplinary experience in US co-creation, as "very different professional groups cooperate with other locations (…). That always means having a lot

of time (…) at the beginning (Person 4, Focusgroup 2, No.2021). All parties have to find their common language and attitude, in which interdisciplinary working experience is a requirement (c. table 2).

Toolbox

Respondents describe their experience overcoming misunderstandings: "If you notice a problem with the overall communication, you should establish a series of workshops (…) (Person 1, Focusgroup 1, No.2021). Kurzhals (2021) highlights that methods for mutual communication are essential at an early stage. Such tools are the prerequisite for successful co-creation to overcome possible barriers (Schmidt & Schönheim, 2021).

Table 2 The USC defined factor "activity" by academics from the quantitative study and focus group

	Quantitatively pre-determined co-creation factors		***Quotes from the focus group***
Factor category	**literature-based co-creation factors**	***Co-creation factors based on academics' experience***	
Activity	*Products/Services*		
	Experience in enterprise		
	Quality of scientific Work		
		Open towards development	*"In almost every regional field, you have many different approaches that you have to consider. That means you have very different professional groups with whom you have to deal, very different worlds, settings with which you have to deal, and in principle, you have to be able to get involved." (Person 6, Focusgroup 1, No.2021)*
		Interdisciplinary experience	*"We have had an excellent experience with this interdisciplinarity in the sense of the diversity of backgrounds, which was also very central for us. In general, I have to say that in networks, multiprofessionality or interdisciplinarity in cooperation is sometimes also a culture that emphasises the disciplinary backgrounds (...)."(Person 3, Focusgroup 1, No.2021)*
		Experience with cooperation	
		Toolbox of methods	*"Using creative methods when you stuck, and you notice that there is a problem with the overall communication, that you establish a series of workshops, and that of course you also have the support here, (...)".(Person 1, Focusgroup 1, No.2021)*
		Non-scientific publication	
		Quality standards of one's work	

Output

Improving the quality of life

Academics can contribute to solving problems through their knowledge because, in US co-creation, academics pursue an overarching goal for the benefit of social actors (Perkmann et al., 2013). Similarly, interviewees reported that they defined a goal collaboratively with the social actors by doing an "identity process that was exactly about working out for us with the network partners what can be a common goal" (…) (Person 5, Focusgroup 2, No.2021) Change of perception. During co-creation, the parties' attitudes change (Perkmann et al., 2013). Furthermore, overcoming the collaborative challenge develops a sense of community (Schmidt & Schönheim, 2021), up to the level that "analogies could be formed, (…) and similarities were found (…)" (Person 2,

Focusgroup 2, No.2021). The interviewees reported that a sense of community emerged after the identification process and the initial process of getting to know each other (c. table 3).

Table 3 The USC defined factor "output" by academics from the quantitative study and focus group

	Quantitatively pre-determined co-creation factors		***Quotes from the focus group***
Factor category	**literature-based co-creation factors**	***Co-creation factors based on academics' experience***	
Output	*Objective*		
	Improvement of life		*"That perhaps in University Society cooperations we have overriding goals, social relevance, relevant things to move, where perhaps this balance of "win-win" no longer plays such a role, but rather we are more concerned with what matters." (Person 2, Focusgroup 2, No.2021)*
	Change of perception		*"You can (…) also feel part of a movement that is trying to use this regionality to simply bring momentum into something bigger (Person 1, Focusgroup 1, No.2021)*
	Companies and start-ups		

Outcome

Gain in knowledge

In addition to the content gain that results from a common goal (c. table 4). and a "shared idea (…) where does research perhaps stay in the region" (Person 2, Focusgroup 2, No.2021), unique and novel ideas can be developed through knowledge generation (Giuliani, 2010). Indeed, through US co-creation, a transfer of knowledge takes place from which the region can benefit and contributes, for example, to economic growth in the area (Al-Youbi et al., 2020).

Regional network

As a result of the existing co-creations, incorporated as a resource in the US co-creation process (Kurzhals et al., 2022), new long-term co-creation partners emerged. With the increasing experience of co-creation and identity formation, attitudes change (D'Este and Patel, 2007), and qualitative co-creations occur (c. table 4). In addition, the network develops new ideas and overcomes knowledge gaps (D'Este & Perkmann, 2011). In other words, "A network works better than a single person because they have a whole network behind them that can deal with it" (Person 7, Focusgroup 1, No.2021), as a participant in the focus group explained.

Table 4 The USC defined factor "outcome" by academics from the quantitative study and focus group

	Quantitatively pre-determined co-creation factors		***Quotes from the focus group***
Factor category	**literature-based co-creation factors**	***Co-creation factors based on academics' experience***	
Outcome	*Companies & Start-Ups*		
	Gain in knowledge		*"I think that from the beginning when you have something in the project framework, you have to negotiate something differently, so that you get a common idea of where research might remain in the region (…)" (Person 3, Focusgroup 1, No.2021)*
		Regional network	*"That means that if you need certain resources, certain ideas, you can quickly get into the network, ask who thinks that, then always take part in a short exchange and then it works." (Person 3, Focusgroup 1, No.2021)*
		SMART Goals	

Impact

Change of perception

At the beginning of the co-creation, the social actors had the feeling that they would not benefit from co-creation until they took part in an initiated identity process. As soon as the first similarities through professional careers were recognised and the interest of the academics in the region became apparent, there was an increased willingness to cooperate. By identifying the project and its problem and new ideas through co-creation, the willingness for a long-term, stable network was present (c. table 5).

Table 5 The USC defined factor "impact" by academics from the quantitative study and focus group

	Quantitatively pre-determined co-creation factors		***Quotes from the focus group***
Factor category	**literature-based co-creation factors**	***Co-creation factors based on academics' experience***	
Impact	*Gain in knowledge*		*"I think that from the beginning when you have something in the project framework, you have to negotiate something differently, so that you get a common idea of where research might remain in the region (...)"(Person 1, Focusgroup 1, No.2021))*

USC Supporting Mechanism

Policies & Guidelines

Based on Cyert and Goodman 1997, organisational differences can cause barriers and transcend these through appropriate structures and management (Perkmann et al., 2011). However, the interviewees emphasised that the funding agencies' requirements had hindered them during the US project based on project management requirements (c. table 6). Academics followed project-related guidelines, although "much was outdated and no longer feasible in the current development" (Person 2, Focusgroup 2, No.2021). The interviewees demanded a free design in the process, e.g., project management, to act stylishly and practically.

Strategy

Strategies are essential for higher education institutions, especially in the long-term implementation of decisions, and offer a way to keep HEI goals focused and achievable (Davey & Galan-Muros 2013). Respondents also rated the importance of strategies within US co-creation as essential. In addition to the established higher education goals, co-creation needs a plan for an optimal transfer of information. In other words, transfer strategies should provide a flow of information between funding agencies, HEI management, academics and social actors (c. table 6). The equal distribution of information can bridge the differences in cultures (Perkmann et al., 2011) to bring all parties to the same level of knowledge needed for successful co-creation (Schmidt & Schönheim, 2021). Finally, the project's start requires crucial communication within the identity process.

Funding programmes

The governments ' funding decreased in parallel with the crises (Makkonen, 2013). Such a financial decrease harms co-creation (Bercovitz & Feldmann, 2006). Still, in the case of US co-creation, the duration of funding programmes is more important than the budget. In US co-creation, social challenges are solved jointly, for which adequate time planning

is needed (Schmidt & Schönheim, 2021). Especially in the transfer process, co-creation parties have to go through a familiarisation process (Kurzhals et al., 2021). This aspect is often not included in the funding programme (c. table 6). Within the familiarisation phase and method, identity develops between both actors by defining a common goal for the society's benefit. In addition to this primary objective, academics must also produce data and results to present to the funding authority. On the other hand, the social actors cannot benefit from these research results. Consequently, a temporal expansion of these funding programmes should focus more on the pooled results of the US co-creation partners.

Table 6 The USC defined factor "supporting mechanism" by academics from the quantitative study and focus group

	Quantitatively pre-determined co-creation factors		***Quotes from the focus group***
Factor category	**literature-based co-creation factors**	***Co-creation factors based on academics' experience***	
Supporting mechanism	*Guidelines*		*"You can also see that with the project organisers, that is written down, that you have to conduct many things, which are outdated or are no longer feasible due to current developments. (Person 1, Focusgroup 1, No.2021)*
	Strategies		*"Ideally, I would say yes, and the transfer must take place in both directions, i.e., on the one hand, a translation aid and on the other hand a mediation" (Person 6, Focusgroup 2, No.2021)*
	Structures		*"I think the difficulty with the funding policy is to fund many projects that always last three years, or five years if you're lucky, but then to stop them because you think you have to finish them in that time. Unfortunately, that is not the case." (Person 1, Focusgroup 1, No.2021)*
	Activities		*"We have carried out an identity process that was aimed precisely at finding out with our network partners what a common goal can be (...)" (Person 3, Focusgroup 1, No.2021)*
	Mutual influence of academics		
	Incentives for commercialisation		
		Social events	

3.7 USC Circumstances

Driver

Co-creation factors contributing to fostering co-creation are *resources*, the potential to *generate knowledge*, a *common goal, project-related motivation* and a direct *added value for the region.*
Resources, which can be in the form of human-related resources and digital resources (cf. input), offer the potential to reach a wider audience (c. table 7). At the same time, human-related resources with the attributes of, e.g. empathy enable an accelerated willingness to cooperate. Knowledge gain can ease the challenge of convincing social co-creation partners to collaborate. In other words, the mutual benefit of all actors promotes the course of co-creation and the associated motivation. To make this common benefit recognisable, a *common goal* and joint questioning support the start of co-creation. In addition, the social actors can be particularly encouraged to cooperate if the social *actors' region can benefit* from the co-creation. The interviewees also emphasised that intrinsic and *project-related motivation* is crucial to transfer this motivation to social actors.

Barriers

The interviewees evaluated that the *third-party funding agreements' requirements (loss of freedom)* were barriers. Here, participants stated the difficulty of balancing between the organisations' and the social actors' requirements. Particularly challenging are the requirements for providing evidence of research data and results and, at the same time, generating benefits for society.

Table 7 The USC defined factor "circumstances" by academics from the quantitative study and focus group

	Quantitatively pre-determined co-creation factors		***Quotes from the focus group***
Factor category	**literature-based co-creation factors**	***Co-creation factors based on academics' experience***	
Circumstances	*Access to resources*		
	Gain in knowledge		*"I think that from the beginning, when you have something in the project framework, you have to negotiate something differently so that you get a common idea of where research might remain in the region, without having to say 'yes, research takes its research share out of it and the region also gets its morsel of development approach out of it'". (Person 5, Focusgroup 2, No.2021)*
	Loss of freedom		
	Delay in publications		
		Objective	*"This is not supposed to be an exchange process, so we have done an identity process that aimed precisely at finding out for ourselves with the network partners what a common goal can be in order not to have to do this win-win because the win-win is just as bad a balance in the end. (Person 2, Focusgroup 1, No.2021))*
		Low administrative burden	
		Project-related motivation	*"If I am enthusiastic about an idea, I might also be able to inspire other people. So I think the intrinsic motivation in oneself also radiates to the potential partners that one can win. (Person 1, Focusgroup 1, No.2021)*
		Diversity of cooperation partners	
		Benefits for the region	*"I think that from the beginning when you have something in the project framework; you have to negotiate something differently so that you get a common idea of where research might remain in the region" (Person 4, Focusgroup 1, No.2021)*
		Bringing research results into society	
		The ratio of presence/digital contacts	

USC Context

Co-creation factors that influence the US co-creation process but cannot be changed are *academic age* and *professional experience*, *a sympathetic appearance*, *believable interest*, *groundedness* and *connection to the region*. Understanding other disciplines and their mindset and responsibilities make US co-creation and its success run smoother. Furthermore, academics must appear sympathetic regardless of their rank. The academics facilitate the entry into the co-creation starting at an " equal level". Similarly, if there is no fundamental interest of the co-creation partners in the counterpart, it slowly makes the course of co-creation more complex and successful. The same goes for the grounding. A co-creation requires a fundamental attitude and a slow start of co-creation (c. table 8).

Table 8 The USC defined factor "circumstances" by academics from the quantitative study and focus group

	Quantitatively pre-determined co-creation factors		***Quotes from the focus group***
Factor category	**literature-based co-creation factors**	***Co-creation factors based on academics' experience***	

Context	*Academic age*		*"By interdisciplinary experience, I mean that this has already been worked through and that this person knows that things can be misunderstood. For example, "we are the mechatronics and know exactly how a care documentation system is structured", but deny that the nurses, for example, already work with it every day. (Person 1, Focusgroup 1, No.2021)*
	Rank		
		Communication skills	
		Ability to work in a team	
		EDP knowledge	
		Sympathetic appearance	*"Professor came, had a good positive appearance (…) like sympathy, for example, which play a role, were essential for us have not only helped well but were important." (Person 1, Focusgroup 1, No.2021)*
		Interest in the other person	*"Of course, if there is someone who grew up in the region and is simply trustworthy, that is also a great door opener, but it doesn't have to be on the birth certificate, but it has to be credible somehow." (Person 3, Focusgroup 1, No.2021)*
		Groundedness	*"For example, when we visited Entwickland, there was a poster with words in Low German, and we immediately got into a conversation about it, and that was immediately a level where the developer realised ", yep, there's someone from a corner who knows certain terms", and so on. Ultimately, that was a very decisive point" (Person 2, Focusgroup 1, No.2021)*
		Pragmatism	
		Connection with the region	*"I have citizens right in front of my eyes who typically come to mind, or you have an idea of the place, of the region you are in, and then I think you can imagine health and the question of what keeps people even better than if you only think about the whole thing in terms of a model integrated chain"(Person 1, Focusgroup 1, No.2021)*
		Language skills	
		Perseverance	

4 Discussion

The results of the present study show that the literature-based co-creation factors differ from the experience of academics in co-creation projects. This deviation can be attributed to the basic attitude in USC projects. While UBC projects focus on the win-win idea (Galan-Muros, 2019), USC projects focus on the collaborative goal of contributing to societal well-being.

Based on the first factor of the USC process, human resources are essential as inputs in both the UBC and USC. However, in the US co-creation, the focus is on interpersonal attributes. In the UBC process, the focus is on the various individual actors (HEI manager, researcher, lecturer, students) and the benefits they bring (Galan-Muros, 2019). In the case of human-related resources, academics must be sensitive towards social actors and society to counteract existing prejudices positively. Besides the human-related subcategory, financial resources are needed at the beginning of the co-creation. While the UBC model emphasises the need for funding (Bercovitz & Feldmann, 2006) and the various funding, USC's funding period is more crucial. Here, funding agencies must pay attention to extending this period and reducing the number of co-creations, thus putting quality before quantity.

In addition, applicants should pay attention to this aspect when formulating applications by giving the task packages appropriate periods to contribute to societal well-being actively. Physical resources are described in the UBC process as a prerequisite for the start of co-creation (Galan-Muros, 2019), while in the USC subcategories such as time, regional network and affective-social resources were named as essential and described in the focus group. As a result, academics need to allow sufficient time for the “findus process” to build the relationship with social actors and society to build trust (Selander et

al., 2010). Due to prejudices, direct access to social actors and organisations is complex. Hence, academics should have a regional network to draw in the USC. Otherwise, academics need to use their sensitive nature to create a sense of community, which requires more time for a shared identity process. Secondly, the "activity" of the UBC differs from the USC in that the UBC context focuses on teaching, research and valorisation.

Meanwhile, in the USC context, the focus is on the experience of academics and methodological tools to overcome communication problems. Consequently, academic workers should already have interdisciplinary expertise in dealing with diverse professional groups and attitudes in the HEI context. As it is important to find a level with these groups to have a conflict-free co-creation (Schmidt & Schönheim, 2021). Furthermore, academics should know about methods (e.g. toolbox) to refer to in case of communication difficulties e.g. in diverse society environments. Then early communication and assistance through co-creation methods is important (Kurzhals et al., 2021). The generated output of UBC focuses on the diverse target groups of the UBC process (academics, business, HEI and students). In contrast, the USC process achieves outputs, such as publications and new products, with a focus on the welfare of society. With other words, USC aims to make a positive contribution to society (Perkmann et al., 2013). Academics can achieve societal wellbeing by improving the quality of life through their knowledge and positively shaping and changing the initial attitude of social actors and culture during the co-creation process. Because it applies that co-creation attitudes and behaviours change through co-creation experiences (D'Este and Patel, 2007). Like the UBC outcome, the USC outcome fills knowledge gaps and develops the potential for long-term ideas for academics and social actors. Hence, the goal of academics and funding agencies must enable knowledge generation in society. Indeed, co-creation leads to a transfer of knowledge from which the region can benefit, e.g. through economic growth in the region (Al-Youbi et al., 2020).

As academics gradually gain the trust of social actors and community (e.g. through identity processes), long-term networks develop useful for further idea generation. UBC's "impact" is consistent with USC, as in both methods ", impact" helps to improve reputation and image (Ahrweiler et al., 2011). This change occurs by changing the initial attitudes of social actors through patience and sensitivity on the part of academics. USC's supporting mechanism calls for the framework conditions of the funding projects to be adapted to current standards for time efficiency. In addition, the transfer managers should communicate the strategies at the beginning and before the start of the co-creation so that the exact distribution of roles is made possible for harmonious co-creation. The funding programmes need to change USC in order to achieve these goals in the long term. The desired goals of societal well-being can only be achieved if sufficient time is allocated to overcome social challenges (Schmidt & Schönheim, 2021). At the same time, the outdated specifications of the funding programmes hinder the project's progress. Especially when selecting USC employees, considering unchangeable co-creation factors is essential in which a justification is not possible. Consequently, when hiring and matching responsibilities in USC projects, consideration should be given to professional experience, a sympathetic appearance, a credible interest and an interest in establishing a connection with the cooperating region. Particularly in the case of externally funded projects, employees are selected and hired specifically for the projects. These characteristics have an essential impact on the process and cannot be changed. Circumstances include drivers and barriers. If the previously mentioned resources flow

in at the project start, the promised knowledge generation for the population occurs, and a common goal for the cooperating region develops; this will ease the co-creation.
In contrast to previous literature, which has focused on an entrepreneurial type of co-creation (Galan-Muros, 2019), we contribute to the literature by going beyond the original co-creation factors and identifying the importance of this joint success. This new perspective underlines the need for academics to be aware of the intention of the co-creation and possibly unique and previously unknown hurdles to overcome before the co-creation begins. In addition to these theoretical implications, these results also aid and advice for project managers, transfer offices and funding agencies, which often pull the strings in USCs and provide funding.
Furthermore, we enrich the existing UBC ecosystem by focusing on the differentiating challenges in the university-society co-creation context and providing guidance on when to pay attention. The previous focus of the research was on university-business co-creation, in which the focus was on the win-win idea (Galan-Muros, 2019). To create distinctions and similarities to this approach, we offered literature-based co-creation factors for evaluation in this study. We allowed respondents to name co-creation factors not yet identified in the literature based on their experiences to broaden the research approach. These newly appointed co-creation factors have been discussed and justified in detail by the participants in the focus group.

5 Conclusion

This study aimed to (1) identify influencing co-creation factors for co-creation projects between HEIs and society partners, (2) determine these influencing co-creation factors affect the project. We carried out a qualitative approach to achieve these goals, conducting a focus group. We surveyed academics from TM's field and social innovation at German HEI for this research. Furthermore, we discussed findings with academics from the "münsterl.land.leben" project. By identifying diverse influencing co-creation factors that affect co-creation between HEI and social actors, we have also been able to determine the kinds of influence and present them in a framework.

The basis of these co-creation factors is the "UBC ecosystem framework" (Galan-Muros, 2019), and includes other respondent-based co-creation factors. Parts of the co-creation factors were selected based on the literature (Academic Engagement Framework (Perkmann et al., 2021); Co-delivery of social innovation (McKelvey & Zaring, 2018)), and respondents rated them as essential, but there were significant deviations in the subcategories. Such variations were evident when considering the experience reports on the co-creation factors. It became apparent that co-creation between universities and companies differs from USC in having already formulated differentiated goals in advance.
On the one hand, the universities, as academics, must provide the funding agencies with accountability for the results and data; on the other hand, the focus is on the social wellbeing during the US co-creation. Definitive statements included defining the "common goal" and "knowledge gain" for both parties. Moreover, co-creation at USC

starts one-sidedly, and the academics with the TM have to motivate the social actors and the societal players to cooperate.

For all parties involved in USC (academics, social actors, society, transfer managers, funding agencies), these results show that paying attention to these mentioned co-creation factors in the co-creation process can prevent unexpected challenges and optimise this co-creation. Such as financial impact on co-creation (Bercovitz & Feldmann, 2006) could be prevented. In addition, the findings on the influencing co-creation factors provide funding agencies with information on the extent to which USC projects need modification within the framework of the guidelines (e.g. prolonged identity process). The same applies to transfer managers, whose multi-layered communication between academics, social actors and funding bodies is in demand. Hence, an equal distribution of information brings all parties to the same level of knowledge needed for successful co-creation (Schmidt & Schönheim, 2021). Furthermore, the research findings offer insight into the impact of employee selection (e.g. interdisciplinary experience) and its importance in collaborative behaviour and how this can lead to long-term collective success.

This study has multiple limitations that need to be reflected. As such, the results presented and discussed do not include all of the statements made by the focus group members, as this would be beyond the scope of the report. Instead, we have limited to the most meaningful and frequently occurring statements in the tables of the respective co-creation factors. In other words, we have chosen a condensed presentation of the results to provide an overview of various aspects. Furthermore, the quantitative study that we conducted has some limitations. The limitation is due to the small number of participants in the survey, which thus limits the evidence of the results. Furthermore, only "münsterl.land.leben" project members and academics who have cooperated in a single region in Germany participated in the focus group, thus bringing the societal attributes of this region into the discussion. As a result, the statements and experiences of the participants are similar; transferring it to the other areas is limited possible. Consequently, the subjective perspective of the regional connection has to be considered. Some focus group participants indicated experience in further co-creations, while others had little to no experience with co-creations and explicitly with USC beforehand. As a result, we cannot guarantee a generalisation of the identified co-creation factors.

So far, little research has taken place within the USC framework. This study is a step in this direction, and we hope that the researcher extends this model to other target groups, e.g. other regions and their field reports. The target group of the quantitative and qualitative research should be extended to social actors. In addition, a quantitative study should be conducted to determine the interaction of the individual co-creation factors within the co-creation through a long-term analysis. Academics, social actors, transfer managers, and funding agencies would also benefit from this information on how the other target groups (e.g. social actors) assess these co-creations.

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Virtualisation of Research and Innovation Infrastructures Supporting University-SME Collaboration

Petri Pohjola[1], Hanna-Greta Puurtinen[2]

[1] Tampere University of Applied Sciences, School of Industrial Engineering
[2] Tampere University of Applied Sciences, Unit for External Funding

Abstract
Increased competitiveness of European industrial SMEs requires intensive and agile efforts on experimenting, adopting, and exploiting new greener technologies and services. Providing better access to universities' research and innovation infrastructures and platforms committed and implementing sustainable and responsible operations can significantly make a difference in this value creation.

With the pandemic, the importance of digitalisation especially through virtualisation has been highlighted and irreversibly changed practices university-SME cooperation. Virtualised research and innovation infrastructures enable new responsible and sustainable service models to be developed to complement activities implemented within existing physical environments. Offering sustainable way of improving awareness levels, understanding of technology investments and opportunities with university – industry collaboration among the users.

Virtualisation of TAMK FieldLab as part of its new service pathway design constitutes one essential element in a process of creating a holistic Sustainability Plan for TAMK FieldLab. In addition to sustainability measures building on digitalisation, this Sustainability Plan will involve physical dimension in terms of, e.g., equipment and materials' life-cycle management, utilisation of renewable raw materials and energy sources, and effective recycling. We are convinced that making this visible also encourage our industry and SME partners for long-term, committed engagement and co-creation.

Keywords
Virtualisation, Research and innovation infrastructures, SME, collaboration, twin transition.

1 Introduction

1.1 Main problem addressed in the paper

Science and technology are not just about theory, neither for universities nor for SMEs. Acquiring necessary and up-to-date technological and innovation skills and competencies for the engineering profession as well as maintaining and upgrading them during working career requires in-depth and continuous practical expertise and experience. Only hands-on experimentation enables thorough understanding of the properties of various mathematical, physical, chemical and mechanical phenomena. In this, universities' research and innovation infrastructures provide unique potential for capacity building, empowering university-SME engagement, and business support.

Research and innovation infrastructures often require extensive and long-term investments in both new technology and high-level expertise. In addition to competence building, they play a key role as universities pursuit towards sustainable and responsible research and innovation in accordance with the United Nations' Principles for Sustainable Development Goals.

With the COVID19 pandemic, digital tools and processes have been widely developed and adopted. This has had profound consequences to university-industry collaboration practices in general. Particularly physical use of laboratories and their equipment has been widely limited during the last two years. For many professions such as those in health care and engineering, hands-on practical training is essential for the progress of studies and acquiring necessary and safe professional skills for employment and work life.

In this challenging and rapidly changing operation environment, new service models and practices in university-SME cooperation need to be developed. Digitalisation is certainly one of the main drivers for this transformation. However, as we show in our case initiative concentrating on the virtualisation of research and innovation infrastructures, this regeneration process allows for holistic incorporation of additional core features such as sustainability and responsibility.

1.2 Main goal of the paper

As a response to these challenges, Tampere University of Applied Sciences (TAMK) has implemented a virtualisation process of one of its key research and innovation infrastructure, TAMK FieldLab. This digitalisation process is integrated into our co-creative service model creation which aims to improve the efficiency and customer-orientation of research and innovation infrastructures (RIIs) in general and TAMK FieldLab in particular. This model builds on close collaboration with industrial partners and embeds the needed agility for strengthening university-industry collaboration as well as contributing to the ever-increasing requirement for sustainability and responsibility.

The objectives of virtualisation process as part of the larger service model creation for RIIs are:

(10) To increase industry competitiveness by making more effective use of university-based research and innovation infrastructures for the business, especially SME, RDI actions

(11) To facilitate and integrate the twin transition, i.e., green, and digital, also in the context of research and innovation infrastructures

(12) To strengthen capacity building, upscaling and updating of competences and skills of all the quadruple helix stakeholders.

In this practitioner paper, we elaborate the basics of the implemented virtualization process as part of TAMK FieldLab's wider co-creative service model process engaging the regional innovation ecosystem in Tampere Region. This work will set the baseline for the next steps in developing a holistic Sustainability Plan for TAMK FieldLab. The good

practices and lessons learnt can also to be extended to other research and innovation infrastructures in TAMK and furthermore also in international contexts.

1.3 Structure of the paper

The structure of this paper is following. In Section 1 Introduction, we present the main features of the problem addressed as well as the main goals and objectives of the present paper. Section 2 Setting the Scene provides the reader with a wider framework to be investigated in this context, presenting the challenges and opportunities offered by the rapid global and regional change of the operational environment. In Section 3, we introduce the methods of an internal study mapping the potentials and expectations of teachers and students of TAMK School of Industrial Engineering (mechanical engineering) regarding virtualisation of research and innovation infrastructures, case TAMK FieldLab. Furthermore, we explain the main features of the process and the outcomes of a virtualisation of a research and innovation infrastructure as part of TAMK FieldLab's service model co-creation process.

Section 4 Results and Implications presents the results of the internal study as well as introduces a short overview of findings illustrating the main benefits and lessons learnt of the model creation from the point of view of different stakeholders. Finally, in Section 5 Conclusions, assessment of the virtualisation embedded in co-creative service model process so far is concluded. In addition, we point out some risks concerning the approach as well as bring forward a few aspects to be further investigated and evaluated.

2 Setting the scene

United Nation's Sustainable Development Goals (SDG) as well as European Commission's recent policy priorities such as green and digital transitions, resilience, and competitiveness on a global scale are setting the high-level strategic framework for striving towards a just, sustainable, and socially fair world (COM, 2021 350 final; UN, 2015; European Commission, 2020). The European Industrial Strategy identifies three main drivers which will transform our industry, support our small and medium-sized enterprises (SMEs), and keep Europe sustainable and competitive (COM, 2021 350 final). In terms of education and research, the main policy documents guiding the pathway are European Research Area and Digital Education Action Plan (Directorate-General for Research and Innovation of the European Commission, 2020; Digital Education Action Plan, 2021).

Global UN's Sustainable Development Goals challenge companies to pay attention to all these three elements. In the context of the current innovation management approach and the industry case studies presented in this paper, the SDGs most addressed range from Goal 9 "Industry, Innovation and Infrastructure" towards Goal 8 "Decent Work and Economic Growth" and Goal 4 "Quality Education". (UN, 2015)

The framework for the virtualisation described in this practitioner paper is the InnoHEIs project (2019-2023) funded by the Interreg Europe Programme (InnoHEIs, 2022). The project focuses on improving the performance of research and innovation infrastructures by bringing together key partners from different European regions and innovation ecosystems for peer review, knowledge, and good practice exchange. The aim is to jointly tackle the challenge of fragmented cooperation models and structures and pave the way towards more integrated and sustainable service models. The process is implemented in triple helix context, where all stakeholders are actively engaged in regional stakeholder groups and well as international knowledge transfer. As the toolbox for the process is jointly agreed and utilised, the results of individual regions can be compared, and the conclusions and recommendations scaled up to European level. The partners are also committed to share their best practices in developing and supporting regional innovation ecosystems by a more effective utilisation of universities' research and innovation infrastructure on an open Policy Learning Platform sustained by Interreg Europe Programme (2022).

3 Virtualisation of research and innovation infrastructure – Case TAMK FieldLab

3.1 Internal study on potentials of RII virtualisation - Method

At Tampere University of Applied Sciences, the main place for co-creation and innovation support in the field of Industry 4.0 is TAMK FieldLab (https://sites.tuni.fi/fieldlab/). It is a testbed and innovation environment for Industry 4.0 related themes. TAMK FieldLab focuses on increasing links and promoting open innovation among universities, innovation platforms and companies via collaborative places. It serves as an important enabler for TAMK's endeavour to create and implement a transparent customer pathway for TAMK FieldLab. This activity is part of the Sustainable Industry X (SIX) initiative and constitutes an element to formulate *Test before investing* services in our European Digital Innovation Hub (EDIH).

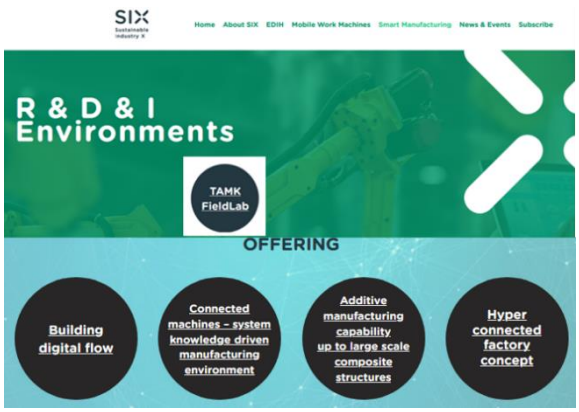

Fig. 1. Example of SIX RDI Infrastructure and offerings (https://www.six.fi/rdi)

The main goal of SIX will be to support Finnish manufacturing SMEs and midcaps on their journey towards a sustainable, digital, and responsible industry. One example of customer pathway in SIX initiative is the descriptions of each RDI-infrastructure's offering as illustrated in Figure 1. Virtual tour of each infrastructure is also provided aiming to improve the understanding of capabilities and use potential within each facility.

During 2021, an online mapping study was conducted among students and teaching staff about the *opportunities of TAMK FieldLab virtualisation*. The questionnaire consisted of a set of questions with numerical response of scale 1-5, 1 indicating "poor" and 5 "excellent" and questions with open verbal suggestions. The questionnaire was sent to two target groups:

(1) Students: 3rd-4th year Bachelor-level mechanical engineering students within intelligent machines study path integrated with TAMK FieldLab.

(2) Staff members: lecturers and teachers of mechanical engineering study programme who have been involved in developing and utilising the TAMK FieldLab.

The online questionnaire was open for answering for two weeks. The responses could be submitted anonymously, however a distinction between the student and staff categories could be made for detailed analysis purposes. The answers were imported into two separate excel files for examination and visualisation.

3.2 Virtualisation process - Methods

Tampere University of Applied Sciences is committed to the above-mentioned UN SDGs as well the objectives of Sustainable Development and Responsibility Program prepared by The Rectors' Conference of Finnish Universities of Applied Sciences Arene (ARENE, 2020). Making these objectives concrete requires renewal of mindset combined with agile experiments (e.g., Viegas et al, 2018). The virtualisation implemented in TAMK's mechanical engineering research and innovation infrastructure, TAMK FieldLab, since spring 2021 strongly supports these universal values and goals, implementing them concretely in every-day actions of the university.

Technically, a high-quality 3D imaging system was utilised in the virtualisation of TAMK FieldLab. Images scanned from the environment were processed into an editable 3D virtual model utilising a third-party server and computing environment. In order to better understand machines and equipment's main features and capabilities within the TAMK FieldLab environment, this 3D virtual model was further supplemented with solution-specific embedded hotspot videos and text.

In connection with the technological implementation of TAMK FieldLab virtualisation, feedback and development ideas were collected from various users and stakeholder groups such as SMEs. This data will be used to co-create new ways to virtualise the environment further. Simultaneously, new ways of university-industry collaboration and

engagement will be jointly developed with SMEs. For example, the concept of the digital twin was identified as a potential topic in which virtualisation can be effectively utilised.

Outcomes created through virtualisation and digitalisation activities are integrated to TAMK FieldLab's service model. This model offers an easy and low threshold access to services as well as a sustainable way of improving awareness levels, understanding of technology investments and other emerging opportunities among companies, SMEs, and other stakeholders. (Puurtinen et al, 2019; Puurtinen et al, 2020; Siivonen et al, 2021)

4 Results and implications

4.1 Internal study on potentials for RII virtualisation - Results

The online questionnaire was sent to 27 3rd-4th year mechanical engineering students and to 30 staff members, mainly lectures and teachers. A total of ten student and 14 staff member answers were submitted in due time.

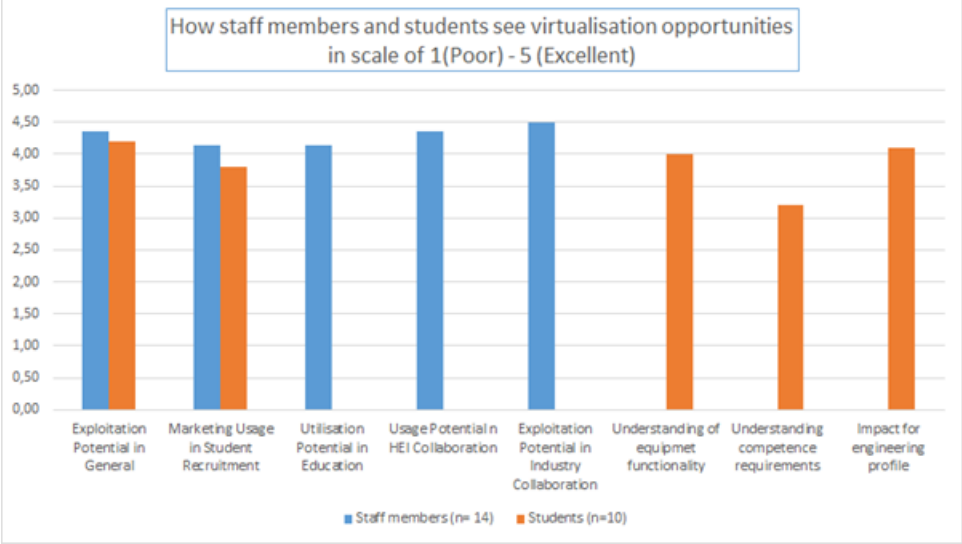

Fig. 2. Opportunities of TAMK FieldLab virtualisation – student and staff respondents

The results presented in Figure 2. indicate that virtualisation exploitation potential in general is considered remarkable. In addition, virtualisation was considered beneficial for marketing usage in student recruitments. The results also indicate that virtualisation utilisation in education has high potential, and it strengthens the profile of engineering profession. Virtualisation is considered to have close to excellent prospects in supporting university-industry collaboration. Additionally, opportunities for marketing usage in student recruitment are seen promising.

As part of the online mapping study both groups were also asked feedback and open suggestions on how this type of virtualised laboratory environment can be more efficiently utilised and leveraged.

Virtual visits to labs are always easier, faster, and safer to organize than real visits.
Distance learning, preliminary tasks of lab teaching. Virtual sales situations.
This is a great way to present lab facilities to both students and various collaborators, especially in these times, but certainly in the future as well.
Laboratory safety training and safety training for students or guests. Remotely trained training would effectively increase the time available for contact time.
The content of the courses could be illustrated through virtualization. Course-specific virtualizations of equipment-related exercises would make it easier to understand the requirements of the course.
The introductory videos highlighted well how digital twins work and what virtualization is in practice. This kind of "kicking" the concept can arouse interest in the field.

Table 1. Feedback and development ideas for virtualisation

The respondents suggest that virtualisation is ideal for guiding, demonstrating, and perceiving the use of almost any authentic space, machine, or device, regardless of time and place. Virtualisation is ideal for laboratory safety training for students and guests, and it would effectively increase the time available for discussion when in face-to-face contact. In this context, it was also proposed that virtualisation would be part of the prerequisites for the course.

4.2 Virtualisation process – Implications

Virtualised research and innovation infrastructures enable new sustainable and responsible service models to be developed to complement activities implemented within existing physical environments. These infrastructures can effectively be utilised in multi-stakeholder cooperation, especially from university-industry cooperation perspective. Many industrial companies, particularly SMEs, need more support for understanding what digital and green transition means for them. For example, uncertainties arise concerning how to expand or boost their business or to build new business models while taking full advantage of those transitions.

Figure 3. Example of the virtualised TAMK FieldLab with specific hot spots.

Accelerating the incorporation of new technologies in the process and product manufacturing cycles such logistics, marketing, prototyping is far from a straight-forward process. It is difficult to demonstrate in a virtualised world the benefits of each technology, as demonstrated by Figure 3. The change factors and parameters emerging from digitised operations or processes should not become too complex in order to assess the key performance indicators for the whole company and its competitiveness.

Digitalisation and virtualisation are renewing the uptake of engineering skills, raising awareness of new technologies and the preconditions for sustainable development. The virtualisation process of TAMK FieldLab showed how the goals of sustainable development and responsibility can be promoted in a university through many concrete actions. The positive impact of the initiative on the employment of students, helping the urgent shortcomings of industry recruitment needs, and the renewal of engineering skills will be directly reflected in leveraging the capacity building and competitiveness of the engaged SMEs.

Virtualisation can create impact on engineering skills renewal and increased awareness level of new emerging technologies. For example, digital twin concept was identified as a potential expertise skill benefitting from virtualisation by both target groups. Impact on employability can be forecasted to improve as both recruiting industry and students gain a better and inspiring view of the learning environments and skills opportunities.

Service pathway with improved visibility as well as increased links and clarified offering between HEIs and companies are promoting collaboration to develop joint projects, using the resources, especially testbeds and research infrastructures in HEIs for testing and prototyping. However, there are difficulties to that were faced during the working process. As result of ever-increasing speed of technology development with continuous emerging technologies and new disruptions in business and players on the field it is challenging to follow the pace of emerging technologies and new innovative concepts during the virtualisation process.

5 Conclusions

In conclusion, virtualised learning and demonstration environment can be considered to possess high prospects for new utilisation purposes and development of new service models of existing, mostly physical infrastructure. Certainly, a set of best practices and novel operational models will continue to be utilised also after the pandemic in a blended mode. to support student employability and engineering skills renewal.

Sustainability and responsibility must be addressed in novel ways being a part of the strategic development and business growth supported by new more sustainable, productive, cost-effective, and flexible investments. In a globally networked business environment sustainability and responsibility are becoming highly respected values, whose implementation in the companies and SMEs must often be proved by standards and KPIs.

Simultaneously, universities must also adopt these same values and keep up to the emerging and strengthening trend while renewing their research and innovation infrastructures and the related service models. This will bring added value not only to the scientific community but also to the innovation ecosystem in which they are embedded.

As we learn to take full advantage of the opportunities offered by digitalisation in new ways, it will take us towards increasingly climate-neutral, sustainable, and responsible institution. In this way, as a university of applied sciences, we will be able to better meet global challenges and create added value for all stakeholders. This work will set the baseline for the next steps in developing a holistic Sustainability Plan for TAMK FieldLab which will combine the physical, digital, economic, environmental, and societal aspects of sustainability and impact.

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