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Insights

Welcome to the May issue of the Technology Innovation Management Review. We invite your comments on the articles in this issue as well as suggestions for future article topics and issue themes.

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Overview
The Technology Innovation Management Review (TIM Review) provides insights about the issues and emerging trends relevant to launching and growing technology businesses. The TIM Review focuses on the theories, strategies, and tools that help small and large technology companies succeed.

Our readers are looking for practical ideas they can apply within their own organizations. The TIM Review brings together diverse viewpoints — from academics, entrepreneurs, companies of all sizes, the public sector, the community sector, and others — to bridge the gap between theory and practice. In particular, we focus on the topics of technology and global entrepreneurship in small and large companies.

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The TIM Review has international contributors and readers, and it is published in association with the Technology Innovation Management program (TIM; timprogram.ca), an international graduate program at Carleton University in Ottawa, Canada.

Editorial: Insights

Stoyan Tanev, Editor-in-Chief & Gregory Sandstrom, Managing Editor

Welcome to the May issue of the *Technology Innovation Management Review*. This issue consists of a mixture of themes structured under our usual "Insights" title.

The issue opens with **André Renz** and **Gergana Vladova's** paper, *"Reinvigorating the Discourse on Human-Centered Artificial Intelligence in Educational Technologies"*. The paper develops the relatively new topic of human-centered AI (HCAI) by presenting a report on how AI systems have been tried, along with how they can be developed in line with human values in a way that poses fewer risks to humanity. The research shows how artificial intelligence-supported educational systems, or AI in education (AIED) has become increasingly relevant for educators and students, while at the same time the EdTech community is still in the early stages of incorporating AI into tools for teaching and learning purposes. While the authors note that AI applications have increased dramatically in recent years, they believe AIED arouses still greater opportunities with massive innovation potential that will have an impact across the education sector.

The second paper by **Wenting Zou, Saara A. Brax,** and **Risto Rajala** addresses *"The Effects of Competence-Based, Expressive and Collaborative Service Performance on the B2B Service Relationship"*. The authors highlight the importance of service performance as an indispensable ingredient in successful business relationships. Yet, due to the complex character of B2B relationships, service performance has become a "multi-faceted issue". The paper investigates the effects of these multiple dimensions on the buyer-supplier relationship. It uses a structural equation model to test multiple hypotheses with a sample of 141 purchasing professionals from 23 countries. The paper concludes by drawing attention to the role service providers have in ensuring business continuity with customers by investing in expressive and collaborative service performance and their impact on customer repurchase intentions. The study is among the first to examine the influence of both service performance and relationship performance on repurchase intentions in B2B services.

This is followed by **Jasmine A. Shaw,** and **Steven M. Muegge's** paper, "Ecosystems, Design, and Glocalization: A multi-level study of Technovation". The authors present a multilevel, embedded case study of the Technovation Girls competition, which is the world's largest technology entrepreneurship challenge for girls. They explore the global and local ecosystems anchored around Technovation, including Mexico and Canada, by first providing a definition of the process and platform that drive this ecosystem. Following this, they identify key architectural features and properties of global-local ecosystems, through a basic literature review. The paper then elaborates a process that can be used for defining design rules in an organizational setting. The authors note that they have "extended the applicability of the ecosystem construct in this paper to a mission-driven, global non-profit organization" (p. 39). Through an analysis of the globalization enabled by this competition, the paper thus offers relevant insights for leaders of current or new global ecosystems, as well as techniques that involve designing a flexible global ecosystem architecture.

The fourth article by **Leena Kunttu, Helka Kalliomäki, Sorin Dan,** and **Jari Kuusisto** presents several *"viewpoints on commercialization and sustainability"* with their work on *"Developing Social Impact Evaluation Methods for Research"*. The authors note that research activities have become more important in dynamic innovation environments and that the social impact of research has not yet come up with an evaluation criterion that has clear metrics. In this paper, they consider the "broader impacts criteria" (BIC) model developed for social impact evaluation in the National Science Foundation in the USA. They propose extensions to the BIC criteria related to commercialization and sustainable development viewpoints on impact evaluation. This makes the newly introduced extension to BIC, called the "inclusion-immediacy criteria" (IIC), an important point of comparison. Based on IIC, the authors propose an extended version of the model that aims to evaluate research impact of research from the point of views of both commercialization and sustainability.

The final paper by **Sten Grahn, Anna Granlund,** and **Erik Lindhult** focuses on *"Barriers to Value Specification when Carrying out Digitalization Projects"*. The authors analysed several digitalization projects that focus on specifications for desired project values, finding out that companies spend comparatively limited resources on specifying desired values in digitalization projects, which limits their success. They then conducted both a literature review, as well as interviews with engineers responsible for production development at 17 Swedish industrial SMEs to gather insights about servitization and value-specification experience. This study aims at addressing

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possible barriers that restrict value specification practices, and at contributing understanding to developing value specification methods that overcome current barriers, to help improve the success rate of digitalization projects.

For future issues, we invite general submissions of articles on technology entrepreneurship, innovation management, and other topics relevant to launching and scaling technology companies, and for solving practical business problems in emerging domains such as artificial intelligence and blockchain applications in business. Potential contributors could also consult the TIM Review topic model (https://topicmodeling.timreview.ca/#/model) to examine the dominant publication themes so far, which might help with ideas for valuable contributions in the near future. Please contact us with potential article ideas and submissions, or proposals for future special issues.

Stoyan Tanev
Editor-in-Chief
&
Gregory Sandstrom
Managing Editor

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Reinvigorating the Discourse on Human-Centered Artificial Intelligence in Educational Technologies

André Renz, Gergana Vladova

> *"I would argue that, however, intelligent machines may be made to be, there are some acts of thought that ought to be attempted only by humans."*
>
> Joseph Weizenbaum (1923–2008)
> Computer Scientist

The increasing relevance of artificial intelligence (AI) applications in various domains has led to high expectations of benefits, ranging from precision, efficiency, and optimization to the completion of routine or time-consuming tasks. Particularly in the field of education, AI applications promise immense innovation potential. A central focus in this field is on analyzing and evaluating learner characteristics to derive learning profiles and create individualized learning environments. The development and implementation of such AI-driven approaches are related to learners' data, and thus involves several privacies, ethics, and morality challenges. In this paper, we introduce the concept of human-centered AI, and consider how an AI system can be developed in line with human values without posing risks to humanity. Because the education market is in the early stages of incorporating AI into educational tools, we believe that this is the right time to raise awareness about the use of principles that foster human-centered values and help in building responsible, ethical, and value-oriented AI.

Introduction

The relevance of artificial intelligence (AI)-supported systems in education, or AI in education (AIED), has increased dramatically in recent years, arousing great expectations and offering huge innovation potential across the entire education sector (EdTechXGlobal, 2016; Holmes et al., 2019). AI has significantly expanded traditional practices in education, while new digital solutions have emerged that are gaining a market share alongside of traditional concepts. Moreover, the use of AI technologies has begun to allow for sustainable change in education and knowledge transfer.

The aim of AIED is to develop adaptive, inclusive, flexible, personalized, and effective learning environments that complement traditional education and training formats (Luckin et al., 2016; Renz et al., 2020a). Popenici and Kerr (2017) defined AI, in the context of education, "as computing systems that are able to engage in human-line processes such as learning, adapting, synthesizing, self-correction and the use of data for complex processing tasks". In addition, AI technology promises to provide deeper insights into learners' learning behaviours, reaction times, or emotions (Luckin et al., 2016; Holmes et al., 2019; Renz et al. 2020a). AI-driven tools can be categorized into two main areas: narrow AI/weak AI and general AI/strong AI. The former refers to an AI agent that is designed to solve one specific task, whereas the latter refers to an AI agent that is capable of solving multiple given problems irrespective of the task or domain. Almost all available educational tools comprise both narrow and general AI together, whereas building a solely general/strong AI is unlikely to exist even in the future (Zawacki-Richter et al., 2019).

Because the outcomes of these tools rely heavily on data produced in a specific task or domain, they affect people in several ways. For example, some are concerned about the use of private information, such as learner behaviours, abilities, and mental states while performing educational activities (Holmes et al., 2018). An increased

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need has therefore arisen to address the technological and societal implications associated with the emergence and use of AIED tools. An ongoing discourse continues about how to better operationalize the various values that arise during the development of AI systems, rather than only applying rules and guidelines after AI deployment.

In this paper, we introduce the "design-for-values" approach, which is based on a methodology aimed at incorporating moral values as part of technological design, research, and development. Developing AI systems entails processes such as identifying social values, deciding on a moral deliberation approach, and linking values to formal system requirements and concrete functionalities (Dignum, 2019). The questions that this research endeavors to answer concern social issues associated with the digitization of education through AIED tools, as well as the changes needed to be made to these tools so that people will accept them as useful and trustworthy. We therefore focus on how responsible AIED tools can be developed and operationalized in a people- or user-friendly way.

In this people-friendly effort, we present several aspects of value-centered, human-centered, ethical, and responsible AI in the domain of education, which in our view still remains underexplored. In the following literature review, we briefly outline current market developments in AIED and discuss AI applications that are currently used in educational technology (EdTech). Based on a conceptual analysis, we combine various HCAI approaches to suggest a new model of how AI technologies can be made increasingly transparent in educational contexts, in a way that can be purposefully adapted to human values for future developments.

AI in Education

Market development of AIED

Implementing AI technologies has high potential for innovation in several fields. In the educational sector, service and product providers are entering the market in increasing numbers. They are offering "intelligent learning solutions" through data-based and AI-driven approaches, such as decision trees, neural networks, hidden Markov systems, Bayesian systems, and fuzzy logic (Aldahwan & Alsaeed, 2020). Although AI-based EdTech applications are innovation rich for the business models of providers and users, still very few EdTech companies have implemented AI technology (Renz & Hilbig, 2020).

Thus, Renz et al. (2020a) have argued that the innovative potential of using AI-based elements in education already exists. The problem is that it often has only been used in a subjunctive role, thus yielding little practical evidence. A worldwide survey of stakeholders in the education sector showed that 20% of the surveyed EdTech companies had already invested in and implemented AI technologies, and another 21% were currently testing AI technologies in their businesses (Global Executive Panel, 2019).

In addition to this emerging innovation dynamic involving AI in EdTech companies, the current COVID-19 pandemic is leading towards a tipping point with faster market development. In a market analysis of two AI-driven EdTech applications, focused on language learning platforms (LLP) and learning management systems (LMS), Renz et al. (2020b) demonstrated that the COVID-19 pandemic has already caused a market shift from low-data business models to data-enhanced business models. The authors had assumed that the significant increase in the use of EdTech applications during the current health crisis would also lead to the market entry of more data-driven EdTech applications. The increasing number of users of EdTech applications has led to generating more data related to learning behaviours and outcomes. Such data provide a basis for further developing AI-based learning systems, in cycles of testing and iterating.

Additionally, we found that intelligent learning solutions on the market follow a principle of rule and content structure, i.e., the system performs a given task using logical reasoning. These methods are summarized under the generic term of symbolic AI (Haugeland, 1895). Holmes et al. (2019) noted that science, technology, engineering, and mathematics (STEM) subjects have played an important role in the development of such AIEDs. Among the most common AIED applications thus far are intelligent tutoring systems (ITS), which allow individualized learning paths in step-by-step tutorials (Alkhatlan & Kalita, 2018). One reason that STEM subjects are particularly suitable for ITS applications is because they usually have clearly defined rules and a well-structured approach (Holmes et al., 2019). Research has shown that EdTech companies must

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prepare for the development and use of AI technologies, such that they will need to accelerate their own existing innovation dynamics in servicing the education market in the near future.

Current AI applications in education

Ahmad et al. (2020) presented a bibliometric analysis of AI applications in education. The authors divided the field of AI applications in education into ITS, evaluation, personalized learning, recommender systems, student performance, sentiment analysis, retention and dropout, and classroom monitoring. Holmes et al. (2019) provided another overview of current AI applications in education. The authors classified four main types AIED applications: ITS, dialogue-based tutoring systems (DBTS), explorative learning environments (ELE), and automatic writing assessment (AWE). The following chart summarizes the most popular EdTech providers selected according to Holmes et al.'s (2019) classification.

Whether an intelligent learning system operates based on individual learning data on behaviour or whether it is based on logical reasoning is not always known by the user. Nevertheless, it can be expected that an increasing number of EdTech applications will soon be developed based on AIED. It is therefore essential to establish appropriate regulations to ensure the responsible and sustainable development of such applications. Human-centered AI (HCAI) is one possible approach that holds promise for the responsible implementation of AI in education, including educational products and services.

Literature Insights on Human-centered AI

The theoretical concept

Many strands of public and scientific discourse assume that AI technologies will replace the human workforce in an increasing number of areas, thus making humans redundant as employees (e.g. Popenici & Kerr, 2017). Hence, many research projects, such as the European Humane AI project at the Stanford Institute for Human-Centered Artificial Intelligence, and other research institutes, such as MIT and UC Berkeley (Xu, 2019) have undertaken initiatives to work toward understanding the human aspects of AI, in order to develop a more responsible AI that enhances the capabilities of humans rather than aiming to replace them. Although there is no

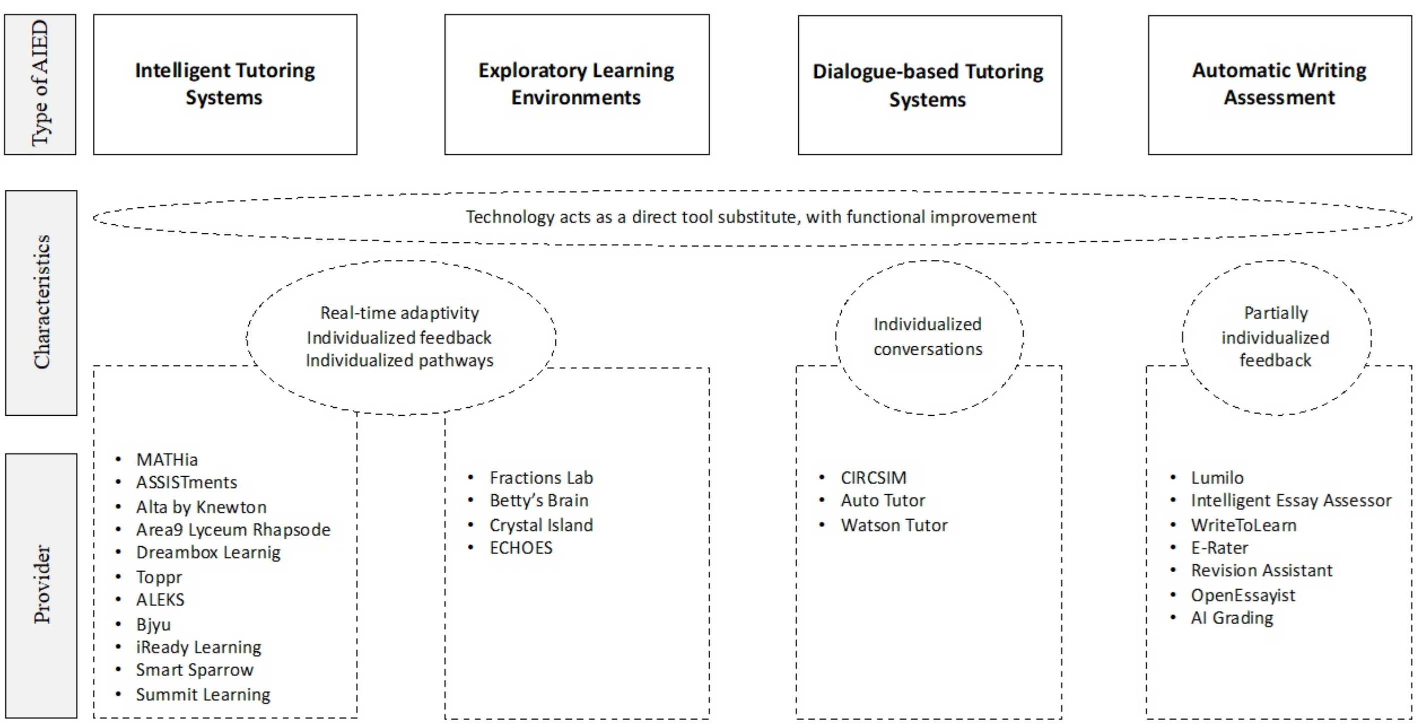

Figure 1. Overview of current AIED applications (Holmes et al., 2019)

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concrete definition of HCAI, the general understanding is that it is a design thinking approach that puts humans at the center of AI development, rather than considering AI automation as a replacement for human agency and control. Furthermore, HCAI "is designed with a clear purpose for human benefit while being transparent about who has control over the data and algorithms" (Schmidt, 2020). Shneiderman (2020) reframed AI as using algorithms to create systems with humans at the centre, thereby framing HCAI with great profundity as our contemporary version of a second Copernican revolution.

In general, it remains unclear which areas of AI development already use HCAI approaches and which don't make HCAI their focus. Nevertheless, various approaches to HCAI development in AI applications have been changed in different areas to achieve better user experiences. One example of implementing HCAI approaches for better user experiences is in the healthcare sector, where, with the help of AI, potential tumors can be identified by X-rays. This application enables radiologists to quickly focus on areas highlighted by the AI and provide targeted treatments for patients (Dembrower et al., 2020). Another growing example of HCAI use is in customer management systems. Some companies employ chatbots and digital agents to automate and streamline responses, which can lead to a less-than-ideal customer experience. The HCAI approach allows the designed (weak) AI system to help the human call center agent by identifying the right information that thereby speeds the answering process by providing better assisted customer experiences (Forbes Insights, 2020).

HCAI Design and Framework Approaches

Despite increased AI implementations for education, not enough attention has been paid yet to the role of human values in developing AI technology. Some scientists have recently started working on design approaches that focus on human values (Auernhammer, 2020). Each of these design approaches provides a valuable perspective on designing for people. One approach called value-sensitive design (VSD) is a theoretically grounded approach to designing technology that accounts for human values in a principled and comprehensive manner. It provides diverse perspectives on society, personal interaction, and human needs in the design of computer systems, such as AI. Hence, the VSD approach provides an opportunity to research and examine through a particular lens the effects of AI on people (Himma & Tavani, 2008; Friedman et al., 2017).

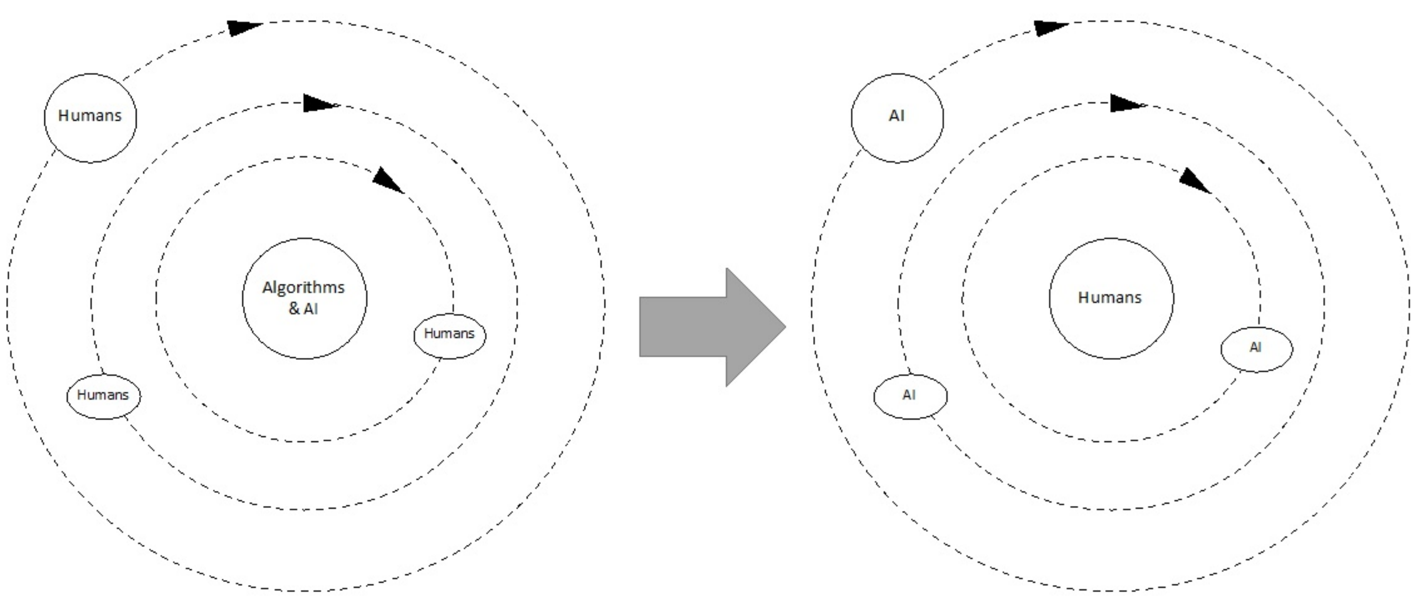

Figure 2. The transformative power of HCAI (Shneiderman, 2020)

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Another solution that mitigates these challenges has been to follow a "design-for-values" methodological approach. This approach aims at making moral values part of technological design and development (Dignum, 2019). Values are often interpreted as high-level abstract concepts that are hard to operationalize in concrete technical functionalities. However, the design-for-values approach has the advantage of placing human rights, human dignity, and human freedom at the center of AI design. Using the design-for-values approach to design has assisted in building HCAI that helps identify social values, and make decisions with a moral deliberation approach (through algorithms, user control, and regulation), thereby linking these values to formal system requirements and concrete functionalities (Dignum, 2019).

Xu (2019) proposed an extended HCAI framework (see Figure 3) that includes the following three main components: 1) *ethically aligned design,* which creates AI solutions that avoid discrimination, maintain fairness and justice, and do not replace humans; 2) *technology that more fully reflects human intelligence,* thus further enhancing AI technology to reflect the depth of human intelligence and character; and 3) *human factors in design* that ensures AI solutions are explainable, comprehensible, useful, and usable.

Every day a wide range of initiatives are taken to establish ethical guidelines and frameworks, acting sometimes with quick solutions to address ethical, societal, and legal problems, in attempting to build socially responsible AI. For example, Algorithm Watch is a non-profit organization that helps point out ethical conflicts. It currently has 150 ethical guidelines for making algorithmic decision-making processes effective and inclusive (https://algorithmwatch.org). Similarly, the AI4People Ethical Framework offers a series of recommendations for developing and adopting AI. The framework is especially tailored to the European context (Floridi et al., 2018). In their meta-analysis of ethical frameworks, Floridi and Cowls (2019) found that almost all guidelines were based on the same set of principles and themes. However, missing was a concrete

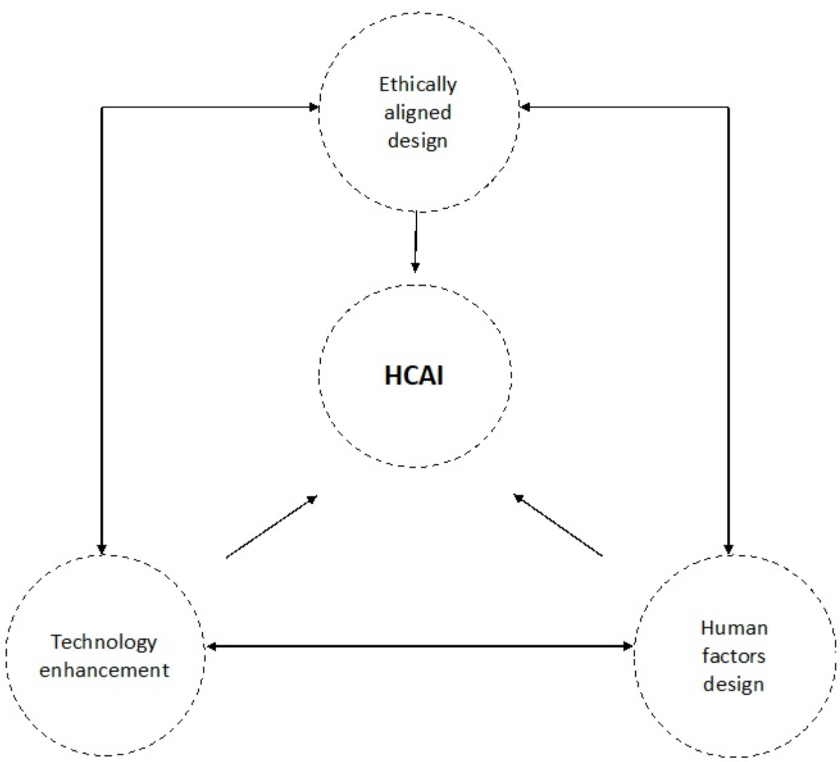

Figure 3. An extended HCAI framework (Xu, 2019)

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methodology for applying and mapping these principles in practice. In addition, the requirements and different levels of understanding about AI across disciplines have become increasingly diverse (Renz et al., 2020a).

Nonetheless, we believe that specific designs for HCAI approaches should be adapted to fit related needs. In the following sections, based on the results of a conceptual analysis, we will propose a framework that combines several HCAI approaches and ideas to derive a map of AI technologies in education and EdTech.

Research Methodology

This paper reports the results of a conceptual analysis that adopts a HCAI approach in the field of education and EdTech. Our conceptual analysis aims to extend a conceptual theory by either postulating a new relationship or establishing that an already known relationship exists between previously unrelated concepts or approaches (Kosterec, 2016). This form of analysis allowed us to introduce the HCAI concept to AIED thinking, as it was not considered in the original theory.

The main steps in the research project were as follows: based on an initial literature review, we identified the current relevance of AI applications in the EdTech market. We aimed to better understand the extent to which AI technologies were already being applied in education, as well as the specific subareas in which recent developments have been taking place. In this paper, the literature review concludes with a presentation of the HCAI approach, along with selected frameworks and designs. So far, few previous studies have followed this approach.

In the next step, we reflected on and combined HCAI approaches in the AIED field to shape a model that aims to structure and address relevant dimensions of the HCAI approach according to AIED applications. Our model intends also to help increase the transparency of AIED applications. For this purpose, we included human-centered dimensions such as trust that are relevant for AI development in the education sector. The results of our analysis showed that discussion involving HCAI approaches is still in its infancy. We believe it is therefore even more important to open the discussion to include new perspectives, which will then be verified in practice, during further research steps.

Results

A human-centered AI approach in education

As AI has gradually been adopted in education for the purpose of teaching and learning, debate has persisted on the educational value of the technology (Luckin & Cukurova, 2019). The fear that AI will make the role of teachers redundant has been offered as a main concern by both teachers and educational institutions (Popenici & Kerr, 2017). As a result of the uncertainty, progress involving AI technology together with learning analytics (LA) in education has lagged far behind other domains, such as healthcare and finance. The AI systems used currently in education enhance already existing technology by providing students with personalized lessons based on their learning patterns, knowledge, and interest in a field. However, ethical issues arise with this usage, as AI requires a large amount of learner data and sensitive information for model training. In addition, questions have been raised about how AI education systems could be theoretically and pedagogically sound (Chen et al., 2021).

We believe that learning technology should be human-centered because it aims at teaching and interactive activities. The HCAI approach now taking shape aims to enhance human capabilities, such as by allowing teachers to build their own computerized lessons using insights gathered from an AI tutoring system (Weitekamp et al., 2020). AI-supported learning environments therefore must not only focus on performance, but also human emotions and outcomes should be main concerns. Further discussion is thus required regarding not only ethics and norms, but also when exploring the effects of “smarter” learning environments on the current technological environment, including learning platforms, and learning communities (Yang et al., 2021). To the best of our knowledge, an HCAI approach has not previously been considered for developing AIED. In this paper, we present a model that uses HCAI approaches for developing and evaluating educational technologies with the intention of offering more transparency to providers and consumers regarding the impact of AI technology.

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HCAI teaming model of education

This section describes the model that was developed from two theoretical perspectives. The two perspectives refer to how HCAI can be interpreted: "AI under human control" (Shneiderman, 2020) and "AI under human conditions" (Stanford HAI, 2020). AI under human control is subject to judgment based on the degree of human control over AI. At one end, AI is fully controlled by humans, and it is used only to support automation. At the other end is autonomy, which is as fully determined as possible by AI. AI in the human condition is a type of reflexive judgment that refers to the design of AI algorithms with humans in mind. This type of AI demands computational and judgmental processes that can be explained and interpreted, as well as continuous adaptations of AI algorithms based on human contexts and social phenomena. We used these two perspectives – AI under human control and AI in the human condition – as a starting point for structuring AI applications for education according to HCAI (Ahmad et al., 2020). Furthermore, following Dubey et al. (2020), we interpreted the interactions between humans and AI as "teaming". In the context of teaming, AI is not only intelligent enough to perform operations and analyze data, but also to work with humans according to predefined rules and structures. Dubey et al. (2020) used the idea of evaluating effective team collaboration between an AI and a human being to develop a taxonomy that captures AI–human teaming concepts. The main components are task characteristics, teaming characteristics, learning paradigms, and trust:

(1) Task characteristics include goals to be solved collaboratively, which can be common, adversarial, or independent; task allocation describes the performance of both people and AI, as well as the variety of roles that capture AI as personal assistant, teamwork-facilitator, associate, or collective moderator.

(2) Teaming characteristics relate directly to integrating people with AI assistants. These vary depending on the relationship between the two entities. They can be described, for example, as fully autonomous AI or with control over humans, as well as responsive to human intervention by volition, or when asked by a machine (that is, "human-on-the-loop"). Teaming characteristics further describe aspects such as observability, predictability, and adaptability.

(3) The learning paradigm addresses both human learning processes (mental models) and AI learning, including supervised, semi-supervised, unsupervised, and reinforcement learning.

(4) Trust is considered vital in the teaming context. It is directly related to the concept of calibrated trust (people are aware of AI capabilities and can adjust their level of trust according to the situation) and interpretability (a person's ability to interpret an AI's behaviour).

We applied a teaming model to structure and address relevant aspects of HCAI and adapt them to the context of educational processes (Figure 4). To represent the task characteristics of AI in this specific context, we followed Ahmad et al. (2020), and proposed assigning the AI applications – ITS, evaluation, personalized learning, sentiment analysis, student performance, recommender systems, retention and dropout, and classroom monitoring – depending on characteristics of the other components of Dubey et al.'s (2020) framework. Figure 4 illustrates our approach using two applications as examples, which we considered to have opposite characteristics: ITS and classroom monitoring.

Classroom monitoring combines the use of Internet of Things (IoT) devices and computational algorithms (for example, computer vision techniques, machine learning, and data analysis) in the classroom. The main goal is to support teachers in their primary tasks of monitoring and analysing students' performances (Lim et al., 2017). Thus, Classroom Monitoring eliminates the need for direct, uninterrupted observation, and allows teachers to focus on the learning process. Similarly, data can be collected and then evaluated later. However, a teacher is always involved by making decisions and initiating changes in the functioning or observational focus of the "social machine" (Berners-Lee and Fischetti, 1999). Classroom monitoring can thus be described as an application that requires high human involvement, along with a low need for trust and supervised learning. Although room occupancy prediction is a longstanding problem, the use of advanced AI technology as a tool to measure or increase the efficiency of room utilization is a new issue. Ethical concerns or limitations arise from, among other things, observing classrooms over an

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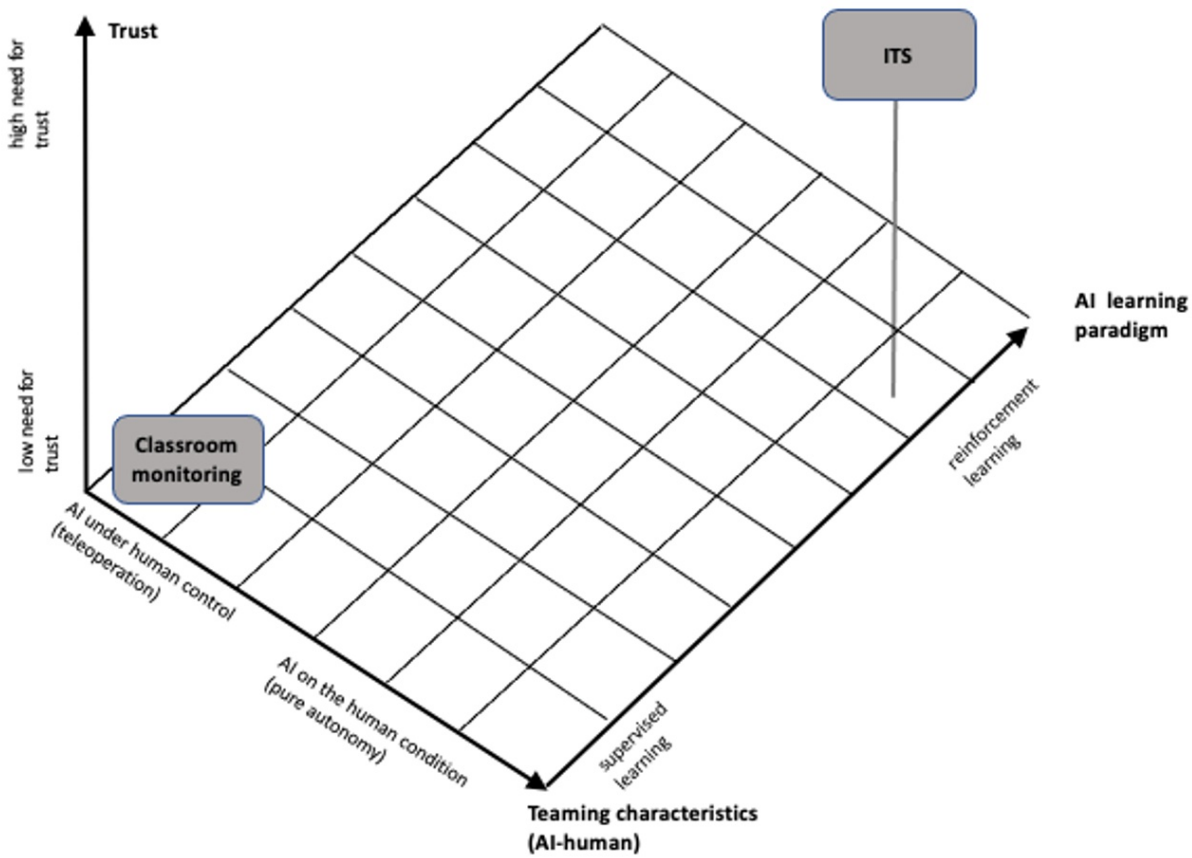

Figure 4. AI applications in education in the HCAI teaming model (authors' visualization)

extended period to analyze teachers' teaching methods and students' learning experiences (Raykov et al. 2016; Ahmad et al., 2020).

ITS aims at providing personalized instruction and feedback to learners often through AI technology and without a human teacher. This aim suggests that, traditionally, AI algorithms and systems have been developed with the notion of harnessing the efficiency of machine automation and optimizing the capability of AI systems. Therefore, our model uses ITS associated with a high degree of AI autonomy, as an unsupervised learning paradigm, with reinforcement learning and therefore a high need for trust. In contrast, we propose building EdTech solutions based on an appropriate HCAI design thinking approach that includes human values and measures human performance, while at the same time remaining amenable to personal feedback and agency that celebrates new human capabilities together with AI (Shneiderman, 2020).

Weitekamp et al.'s (2020) newly developed methods involve AI technologies that allow a teacher to teach an AI system (ITS) that then teaches students. With this AI classroom method, a human teacher demonstrates to the computer how to solve specific problems, such as multi-column addition. If the computer provides the wrong solution to the problem, it indicates to the human teacher potential areas of difficulty for students. This authoring process helps teachers understand students' trouble spots because the machine learning system often stumbles at the same problems that students do. As we face uncertainties regarding whether to enhance machine capabilities or human capabilities, it seems to be the right time to rethink the development of AI systems that aim at satisfying educational purposes. Furthermore, HCAI thus becomes essential in ensuring that AI solutions responsibly prioritize human values and human dignity.

In our HCAI model for AIED, we align the dimensions of

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teaming characteristics with HCAI perspectives (Shneiderman, 2020; Stanford, 2020). Our model could help to structure and address relevant aspects of the HCAI approach according to AIED applications. Furthermore, our model addresses individual degrees in the development of teaming characteristics, learning paradigms, and trust, which aims to increase the transparency of AIED applications. Hence, we also considered Schmidt's (2020) argument that HCAI approaches should establish greater transparency of data and algorithms, which appears to be one of the first steps in reflecting on the use of HCAI approaches in EdTech.

Regarding existing and new AIED applications, our model provides a basic orientation about the degree to which AI technologies relate to human beings and where, if necessary, people should have greater influence on the design and autonomy over the technology. We should keep in mind that AI architecture cannot be fully incorporated into any such model, and thus our model only helps to provide an initial structure. How particular HCAI approaches are designed and implemented in individual EdTech applications could not be mapped in the model presented here.

Overall, we suggest that AI systems should not only keep humans “in the loop”, but also provide higher levels of human control where AI is created under human-centered conditions. HCAI systems should aim to lead to an increase in human performance that achieves higher levels of self-efficacy, mastery, creativity, and responsibility.

Conclusion and Outlook

In our research, we identified the EdTech community as being currently still in the early stages of incorporating AI into educational tools for the purpose of teaching and learning. Even though these AI tools in teaching and learning appear to have great potential, they are scarcely used in current educational institutions. One reason for restraining the development of AIED might be that people are, in principle, skeptical about using or developing AI systems due to often repeated dystopian framings of the concept of “AI”, which Dietvorst et al. (2015) described as algorithm aversion. Jussuopw et al. (2020) showed that the algorithm aversion phenomenon is influenced by various factors, though no investigation has yet looked at whether it is also present in the context of AIED.

Avanade's (2017) study on HCAI demonstrated that 88% of global business and IT decision makers stated that they do not know how to use AI, and 79% said that corporate resistance limits their implementation of AI. Due to this gap in innovation and development, we suggest that EdTech providers should consider developing more HCAI-based approaches to better realise the potential of AIED. This would allow us to more clearly envision the benefits that AI systems have to offer. We propose that now is the right time to consider value-conscious design principles in developing human-centered and responsible AI that addresses social, legal, and moral values prior to and during the technology development process.

In the current market, AIED systems work in one of two ways: 1) rule-based, where the system is given a set of rules and applies these rules to problems to find an answer; or 2) learning-based, where the system observes, finds patterns, and makes predictions independently. However, with the shift toward developing modern learning-based AI systems, concerns have emerged regarding AI that replaces human control, algorithmic violations caused by bad data, socioeconomic inequalities exacerbated by the technology divide, and privacy violations. The AI community has consequently shifted its focus to emphasize HCAI because of mixed public opinions about AI, such as those expressed by actors involved in education and government, as well as private entities, parents, and leaders of institutions.

We thus support the need to rethink how to develop an AI system that complies with human values without posing risks to humanity. Such a shift has not been noticeable because HCAI has the same capabilities as AI, with the only difference being that instead of replacing human workers, HCAI aims at augmenting human workers and enhancing business outcomes with improved human-machine interface. In this paper, we therefore described the nature of the human–AI relationship as “teaming”, and provided an initial framework for structuring relevant aspects of HCAI teaming according to AIED applications.

We believe that educating stakeholders about the potential and utopian capabilities of HCAI will help in

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attaining the common goal of student and teacher success, while reducing some of the anxieties and fears people have of AI systems. An increasing number of initiatives already exist at the public level (for example, Elements of AI in Finland and AI Campus in Germany), which provide information about the opportunities and potential, as well as challenges and risks of AI, thus raising awareness about the topic. In addition, data literacy initiatives have increasingly aimed to improve the general understanding of how data can be (mis)used. Such initiatives and educational projects will contribute to raising social awareness about AI technologies. Further research would benefit from analyzing cases of how HCAI approaches have influenced the development of AIED in the educational market and contributed to application readiness.

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The Effects of Competence-Based, Expressive and Collaborative Service Performance on the B2B Service Relationship

Wenting Zou, Saara A. Brax, Risto Rajala

> *Whether the use of complexity research will fundamentally improve firm performance will depend on the effect on success derived from its application.*
>
> Duncan A. Robertson (2004)

Service performance is considered an essential determinant of successful business relationships. It affects the customer's repurchase intentions and, therefore, the continuity of the relationship between the service provider and the customer. Yet, due to the complexity of B2B relationships, service performance is a multi-faceted issue. It includes at least three crucial aspects: competence-based, expressive, and collaborative performance. The present paper investigates the effects of these dimensions on the buyer-supplier relationship and analyzes their mediated impact on customer repurchasing intentions. In so doing, we establish a structural equation model and test multiple hypotheses with a sample of 141 purchasing professionals from 23 countries. The findings indicate that expressive and collaborative service performance are more significant determinants of successful business relationships and influence business relationship continuity more than competence-based service performance. Also, relationship performance was found to fully mediate the links between expressive and collaborative service performance with customer repurchase intentions. The study underscores that service providers can ensure business continuity with their customers by investing in expressive and collaborative service performance.

1. Introduction

Perception of past service performance plays a pivotal role in customers' repurchase intentions of B2B services. Previous research has shown that customers are more likely to continue business with a service provider they perceive favorably (Hennig-Thurau et al., 2002; Shamsollahi et al., 2020), and that customers' positive perceptions of the service link to stronger customer repurchasing intentions, either directly (Roy & Butaney, 2014) or through buyer-perceived value (Aitken & Paton, 2016). Hence, a positive customer perception of service performance is vital for the sustainable business of service providers. It is especially important for complex B2B services that are difficult to evaluate (Briggs & Grisaffe, 2010).

This study focuses on the impact of service performance on provider-customer relationships, along with customer repurchase intentions. Most empirical studies examining service performance and repurchase intentions are conducted in the business-to-consumer (B2C) context (for example, Antwi, 2021), emphasizing consumer services, retail, hospitality, or online commerce (Tandon et al., 2017). Nevertheless, some studies demonstrate the impact of service performance on the buyer-supplier relationship in the B2B and industrial services context (Doney & Cannon, 1997; Homburg & Garbe, 1999). However, a need remains to analyze further the factors influencing B2B service contract renewal because the linkages between service performance, relationship performance, and customers' purchasing continuity intentions in relational B2B service exchanges constitute a complex setting for purchasing decisions (Bolton et al., 2006).

Service providers need to manage their service performance in several areas. First, because customers are significant contributors to the service process in B2B services, and the element of co-creation is salient, *collaborative performance* has a crucial role in the service process and can significantly influence the service relationship. Second, many industrial and B2B services are sophisticated services that require specialized capabilities and *competent performance* from the providers. Third, successful services characterize *expressive performance*, which implies the parties' satisfaction with their interaction throughout the service activities, both on psychological and emotional levels. Further investigation of the complexity of service performance is needed to understand how the different aspects of service performance contribute to the continuity of B2B business relationships.

The following research question was posed for the study: *How do service performance and business relationship performance affect service contract renewal?* We studied this question by examining the interrelationships between service performance, relationship performance, and customer repurchase intentions through a structural equation modeling (SEM) approach. In the research model, service performance was divided into three dimensions: competence-based, expressive, and collaborative service performance. Hypotheses were tested by analyzing a sample of responses from 141 purchasing professionals in 23 countries. A survey questionnaire was developed and carefully tested to collect the data. The study contributes to the service literature by analyzing the influences of three dimensions of B2B service performance on the business relationship and customers' repurchase intentions.

2. Theory and hypotheses

2.1 Relationship continuity – repurchase intentions

Customer repurchase intention (or likelihood-to-renew the relationship) is often considered as the eventually positive outcome of the supplier and buyer relationship (Shamsollahi et al., 2020). In this sense, repurchasing intentions refer to the buyer's intent to purchase the same or additional services from the same provider, and thus continue the relationship. It can also reflect the buyer's reluctance to switch suppliers. Repurchasing intentions often consist of contract renewals and increased patronage, typically developing into a long-term business relationship (Cannon & Homburg, 2001). In B2B services, a long-term relationship between buyers and service providers facilitates collaborative innovation for the benefit of both parties.

2.2 Relationship performance

Relationship performance reflects the customer's perception of the buyer and supplier relationship (Palmatier et al., 2007). In B2B contexts, the service complexity, long time horizon of delivery, and unfamiliarity of outcomes, increase uncertainties for buying companies (Huo et al., 2016). A good inter-organizational relationship between the buyer and service supplier increases mutual understanding and facilitates adaptations during the service process, decreasing buyer-perceived uncertainty (Roehrich & Lewis, 2014). Although relationship performance is a composite construct that includes several different perspectives, researchers have identified that trust, satisfaction, and commitment form the critical dimensions of relationship performance (Morgan & Hunt, 1994; Barry & Doney, 2011). In the following, these components are elaborated in more detail.

Trust in B2B settings refers to the belief of a party that its needs can be met by the actions of another organization (Doney et al., 2007). Hence, trust is a crucial determinant of successful business relationships. The complexity of B2B services and relational exchange makes trust even more critical because it reduces customer-perceived risks during service interaction (Doney et al., 2007).

Satisfaction has been defined as the buyer's positive affective state in a business relationship resulting from the appraisal of their relationship with the supplier (Selviaridis & Spring, 2007). Smeltzer and Ogden (2002) suggest that it reflects an evaluation of the supplier's overall performance, considering all service episodes instead of focusing on a single transaction. In B2B service exchanges, the process-based and long-term collaboration orientations between the two parties mean that a satisfactory business relationship is critical.

Commitment refers to the buyer's perception of the provider's willingness to maintain a stable relationship in the long run. Different dimensions of commitment, including affective and calculative commitment (Briggs & Grisaffe, 2010; Stauss et al., 2010), exist due to various motivations to continue the relationship. Affective commitment is the desire to maintain the relationship because the buyer has positive feelings for the supplier and may experience a sense of belonging and loyalty in the relationship (Morgan & Hunt, 1994). A buyer's calculative commitment implies the need for relationship continuity, for example, due to substantial switching costs or termination costs associated with leaving the relationship (Stauss et al., 2010). Hence, commitment is critical to organizational buying behaviour in relational exchanges. Existing studies show that the buyer's trust in a service provider and satisfaction in the relationship positively influence the buyer's service repurchase intentions (Zeithaml et al., 1996; Doney & Cannon, 1997; Eggert & Ulaga, 2002). Studies have shown a strong positive correlation between buyer-perceived commitment and relationship continuity (Morgan & Hunt, 1994). Hence, we hypothesize:

H1: Relationship performance has a positive direct effect on customer repurchase intentions.

2.3 Service performance

Customer-perceived service performance is connected with value-creating practices between customers and service providers. Because customers subjectively determine the value of a service based on their experience, customer perception of service performance is key to understanding and measuring the value realized through a service (Vargo & Lusch, 2011; Kohtamäki & Rajala, 2016). In supply chain management research, service performance is commonly evaluated instead of service quality (Stank et al., 2003; Briggs & Grisaffe, 2010). The dimensions of service performance are based on service quality conceptualizations by Parasuraman et al. (1985) and Grönroos (1984), which include the technical outcomes of a service and its functional processes. The complexity of B2B services requires the assessment and management of multiple parameters to ensure effective service delivery. Hence, we identify three service performance dimensions: competence-based service performance, expressive service performance, and collaborative service performance, which separately examine these dimensions' effects. Understanding these dimensions of service performance helps providers allocate their resources effectively and clarifies decision-making related to purchasing business services (Arnott et al., 2007; Briggs & Grisaffe, 2010). The following section elaborates on each dimension.

2.3.1 Competence-based service performance

Competence-based service performance refers to the outcome-achievement of a service grounded on Grönroos' (1984) widely used concept of "technical service quality". Essentially, it describes "what" the customer gains from interacting with the service provider (for example, service-need fit, conformance to specifications, and reliability of operations) (Arnott et al., 2007). Thus, competence-based service performance extends the outcome-focused technical quality concept with service reliability, defined as accurate and reliable delivery of the promised service outcome (Johnston et al., 2004).

The competence-based service performance dimension focuses on activities that constitute the provider's core services (Lindberg & Nordin, 2008). Here, expectations are either based on predefined and formally agreed performance criteria or guided by less formal descriptions of the service offering that facilitate the buying decision, since the core service is the reason that initiates the service exchange. Buyers can therefore often measure competence-based service performance based on this fact. In B2B service contexts, measuring competence-based service performance requires buyers to assess the service reliability in terms of how well the service outcome conforms to expectations (Beltagui & Candi, 2018).

When business customers receive the expected service, the logical outcome is a good inter-organizational relationship between the customer and provider. The literature documents corresponding relationships between expected service outcomes and the three dimensions of relationship performance: trust, satisfaction, and commitment. Prior studies have identified that expected outcomes lead to the buying organization's trust in the service provider (Homburg & Garbe, 1999). Moreover, previous studies have proven that the outcome-related performance of services positively influences customer satisfaction (Homburg & Garbe, 1999; Roy & Butaney, 2014) and can lead to a buyer's commitment to the business relationship (Chumpitaz Caceres & Paparoidamis, 2007). These considerations lead to the following hypothesis:

H2: Competence-based service performance positively influences relationship performance.

2.3.2 Expressive service performance

Expressive service performance concerns the customer's affective reaction to a service. It demonstrates that the service process has characteristics that convey something to the customer on a psychological or emotional level and evokes affective responses (Beltagui & Candi, 2018). Although these reactions include a subjective component, they reflect the customers' experiences of interactions with the provider, thereby essentially contributing to the broader perception of the service by the customer (Doney et al., 2007).

The affective and experience-centric dimensions of service performance have been captured in various forms in the classical service assessment frameworks, including the SERVQUAL instrument (Parasuraman et al., 1985). The SERVQUAL instrument addresses the service experience with five dimensions: tangibility, reliability, responsiveness, empathy, and assurance. Expressive service performance captures three of them - responsiveness, empathy, and assurance, which represent functional service quality as identified by Grönroos (1984). Hence, expressive performance also covers the service provider's support for the customer (Grönroos, 1984; Chumpitaz Caceres & Paparoidamis, 2007).

Researchers have found positive links between expressive service performance, customer trust, and satisfaction in the relationship (Morgan & Hunt, 1994; Doney et al., 2007). In a study of industrial services, Homburg and Garbe (1999) illustrate that a customer's trust, satisfaction, and perceived commitment are all positively affected by expressive performance (operationalizes as "process-related quality"). These arguments on expressive service performance give rise to the following hypothesis:

H3: Expressive service performance positively influences relationship performance.

2.3.3 Collaborative service performance

Collaborative service performance is the customer-perceived performance of collaborating with the service provider during a service exchange, which involves activities and exchange of information to achieve a targeted performance level. In B2B contexts, services are generally co-created through interactions between buyers and suppliers, which requires close collaboration to design, develop, and deliver services (Vargo & Lusch, 2011). Recent empirical studies highlight information sharing as the foundation of cooperation between buyers and suppliers to improve performance (Barratt, 2004). Collaborative performance of B2B services is often estimated by the information sharing, flexibility, and cooperative attitude of suppliers towards the contract (Barratt, 2004; Guo & Ng, 2011).

One of the foundational arguments in the service-dominant perspective (Vargo & Lusch, 2011) is that all services are co-created. Collaboration fosters a relationship between parties with common goals (Guo & Ng, 2011). More precisely, transparent information exchange (De Vries et al., 2014) can increase trust and reduce information asymmetry between parties. Yet, the literature review by Oertzen et al. (2018) pointed out that the ways and intensity of sharing and co-creation vary between different types of service offerings and across service life-cycles. Also, a provider's flexibility that facilitates adaptating to unforeseeable situations and promotes a measured approach to problem-solving can increase customer-perceived commitment to the relationship (Guo & Ng, 2011). Hence, we hypothesize that collaborative service performance, in general, contributes to relationship performance as follows:

H3: Collaborative service performance positively influences relationship performance.

The main argument for distinguishing between competence-based, expressive, and collaborative performance is that assessments of service performance can emphasize outcomes, affection, or cooperation. Research of B2C services demonstrates that service performance is directly linked with customer repurchase intentions (Bolton et al., 2006). Good collaborative buyer-supplier relationships are crucial, particularly in complex services, which are co-designed and produced jointly. According to Caruana (2002), the link between service performance and repurchase intentions is fully mediated by customer satisfaction.

Conversely, if the buyer perceives the underlying relationship as poorly performing, it is unlikely that a repurchasing decision will be made. Briggs & Grisaffe (2010) conclude that customer trust mediates the influence of service performance on behavioral intentions in B2B contexts. Their findings suggest that service performance has only an indirect impact on B2B repurchase intentions. Hence, it is reasonable to assume that relationship performance mediates the effect of service performance on customer repurchase intentions.

In this study, we examine the outcome-achievement, affective and collaborative aspects of service performance. Undeniably, the relational aspects of service performance are accentuated in long-term collaboration. Thus, we hypothesize that the contributions of all three dimensions of service performance to customer repurchase intentions will be fully mediated by relationship performance.

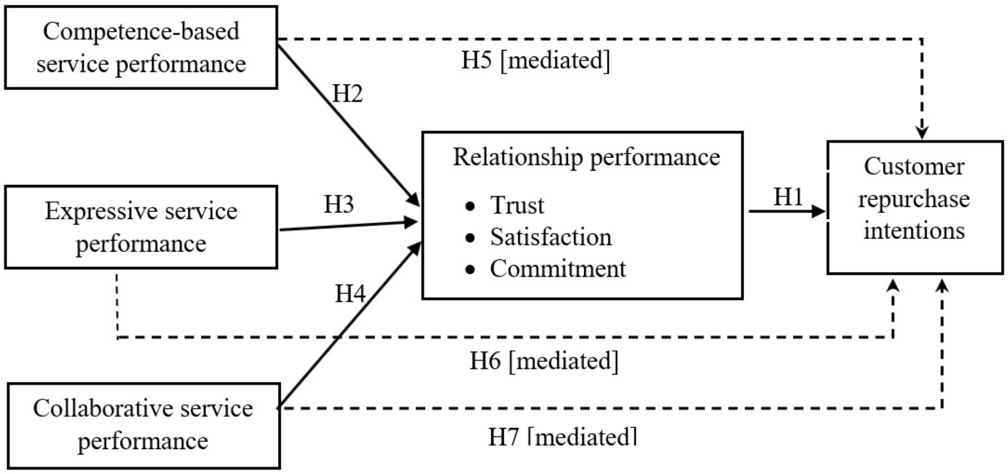

Figure 1. Research Model

H5: Relationship performance fully mediates the positive relationship between competence-based service performance and customer repurchase intentions.

H6: Relationship performance fully mediates the positive relationship between expressive service performance and customer repurchase intention.

H7: Relationship performance fully mediates the positive relationship between collaborative service performance and customer repurchase intention.

The relationships hypothesized above are presented in Figure 1.

3. Research method

3.1 Sample and data collection

The sampling frame of the present study entailed service purchasing professionals whose jobs involve buying business services. We invited respondents from several countries, industries, levels, and functions for a comprehensive analysis of the phenomenon. As the world's largest professional network (Bonsón & Bednárová, 2013), we utilized LinkedIn to identify purchasing professionals as potential respondents for the study. LinkedIn focuses on professional content produces informative individual and organizational profiles, which can be used to identify experts in producing research data (Maramwidze-Merrison, 2016). We selected special interest groups of purchasing professionals to share their experiences, expertise, and knowledge in a supportive learning environment. These groups were considered as an effective way to approach professionals experienced in purchasing B2B services.

LinkedIn's private special interest groups for professional purchasing were used to establish the contact list we used to gain a customer-perceived view of service performance, and its effects on repurchasing. These groups are professional interest groups in which members share information and discuss topical issues in professional purchasing. Membership in the special interest group requires an application and is controlled by the group owner, thus improving the quality of sampling over other social media. The two largest international purchasing private groups were selected as the contact database: Purchasing & Materials Management (https://www.linkedin.com/groups/156598) and Purchasing & Global Supply Chain Professionals (https://www.linkedin.com/groups/50589).

For the initial contact list, we randomly selected a sample of 1,000 individuals from the lists of members of these two groups. We used several techniques to search e-mail addresses, including Google Search and company websites. If a person's contact information was not found on the internet, it was replaced by someone else from these groups. The contact list included 1,000 individuals from 46 countries. This was thus not an entirely random sample, which is a limitation of the study. However, due to the multi-industry context and the large size of the forum groups, we concluded that the members would not likely be more connected than people typically are in an industry.

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We sent potential respondents an e-mail message, including a cover letter and the link to our web survey. Two reminder invitations were sent during our data collection phase. Of the 1,000 prospective informants, 48 were not able to receive surveys due to incorrect or outdated contact information. 55 respondents asked to be removed from the sample (either because they were no longer responsible for service purchasing or because they declined to participate), leaving an effective sample of 897 individuals. During the data collection period between August to October 2015, 141 usable responses from 23 countries were received, for an effective response rate of 15.7%. This falls within the range from 6% to 16% which Dillman (2000) considers acceptable for international internet surveys. Most of the respondents had approximately ten years of purchasing experience in organizations.

3.2 Survey development and measures

Survey items used in this study were derived from measures represented in the literature and then refined through a series of pre-tests. The questionnaire was tested by a marketing researcher specialized in questionnaire design and with a sample of 18 professionals representing purchasing and business functions in public, private, and non-profit organizations. These organizations cover several industries containing utilities, information services, manufacturing, and educational services.

All constructs were measured with the typical reflective view of construct specification. From the original 24-item instruments, two items were removed based on construct reliability and validity tests. All items were measured using 5-point Likert scales with anchors of (1) *strongly disagree* to (5) *strongly agree*, as summarized in Table 1. The respondents were asked to evaluate their most recent purchase. Thus, the responses measure different areas of service performance and relationship performance in a single, dyadic business relationship in their responses with a specific B2B service provider company.

We chose structural equation modeling (SEM) to test the research model. Following Hair et al. (2006), our sample size made SEM a feasible method to test the hypotheses.

3.3 Measurement reliability and validity

As suggested by Anderson & Gerbing (1988), we conducted a procedure for scale development before estimating the structural path to test hypothesized relationships (Tables 2 and 3). First, we estimated items by confirmatory factor analysis, using Stata/MP 13 with maximum likelihood estimation. All items met the criterion for standardized factor loadings (above 0.5) as suggested by Bagozzi & Yi (1988). We tested the reliability of the measurement using Cronbach's α. All of Cronbach's α coefficients exceed 0.7 (Table 3), which provides reliability (Fornell & Larcker, 1981). Furthermore, the average variance extracted (AVE) for each construct was above 0.5, which supports convergent validity as recommended by Fornell & Larcker (1981). The AVE for each construct was higher than the squared correlation between all pairs involving the construct, providing discriminant validity (Fornell & Larcker, 1981), shown in Table 3. Consequently, all of the constructs demonstrate good reliability and validity.

4. Results

4.1 Description of respondents

The sample consisted of experts in service purchasing within companies across a wide range of industries. Table 4 shows the sample's demographic properties. The respondents covered 17 out of 18 industries in our sampling frame (except the arts, entertainment and recreation industry), which follows the North American Industry Classification System (NAICS) (United States Census Bureau, 2014). Also, as illustrated in Table 4, 121 respondents represented the purchasing function, while 20 respondents represented other functions, but had strong interest in purchasing. Most of the 121 respondents that represented the purchasing function in their organizations were middle- or senior-level managers. The average experience of purchasing function respondents was 12.8 years, with 13.8 years for those in other functions. The respondents' extensive experience in B2B purchasing in many industries and countries made their responses both valuable and relevant to the survey.

4.2 Results of hypotheses testing

The hypotheses were tested by SEM and with three structural equation models. Model 1 was established to test H1-H4. Models 1, 2, and 3 together were estimated to test the fully mediated influences H5-H7. The results of the modeling estimations and associated fit statistics are demonstrated in Table 5.

Based on the results of model 1, H1-H4 were supported. Strong support was shown for the positive impact of relationship performance on customer repurchase intentions, thereby supporting H1 ($\beta=0.75$, $p<0.001$).

Table 1. Measurement Scales

Construct	Abbr.	Item	Source
Competence-based service performance	CSP1	The supplier has efficient processes for dealing with our service requests.	(Parasuraman et al., 1988; Homburg & Garbe, 1999)
	CSP2	The supplier's service personnel can handle our requests.	
	CSP3	The supplier always delivers the service on time.	
Expressive service performance	ESP1	The supplier's personnel show that they value us.	(Parasuraman et al., 1988; Homburg & Garbe, 1999)
	ESP2	We believe this supplier considers how their decisions and actions influence us.	
	ESP3	When it comes to things that are important to us, we could count on this supplier's support.	
Collaborative service performance	CBSP1	This supplier is flexible enough to handle unforeseen problems.	(Homburg & Garbe, 1999; Guo & Ng, 2011)
	CBSP2	The supplier honors our contract in practice.	
	CBSP3	This supplier openly shares information with us.	
Relationship performance			
Customer trust in relationship	CT1	The supplier's promises are always reliable.	(Doney & Cannon, 1997; Doney et al., 2007)
	CT2	The supplier is not always honest with us. (Reverse)	
	CT3	The supplier is truly concerned about our business success.	
	CT4	We are confident that this supplier always keeps our best interests in mind.	
Customer satisfaction in relationship	CS1	The service provided by the supplier meets our expectations.	(Homburg & Garbe, 1999; Roberts et al., 2003)
	CS2	The time of service delivery meets our expectations.	
	CS3	Compared with alternative suppliers, we are confident that this supplier will better help us achieve our goal.	
	CS4	We are willing to recommend the supplier without any reservation.	
Customer commitment in relationship	CC1	Our firm is willing to invest in the relationship to make it successful.	(Homburg & Garbe, 1999; Doney et al., 2007)
	CC2	Because of our history, we are loyal to this supplier.	

Table 1. Measurement Scales (cont'd)

Repurchase intentions	RI1	We expect to continue doing business with the current supplier over the next few years.	(Eggert & Ulaga, 2002; Barry & Doney, 2011)
	RI2	We keep searching alternatives to avoid dependence on this supplier. (Reverse)	
	RI3	Our intention is to continue with this supplier as long as possible.	

Table 2. Constructs and Measurement Items

Construct	Item name	Loading	Mean	SD
Competence-based service performance	CSP1	0.85	3.91	0.66
(AVE= 0.62, α= 0.84)	CSP2	0.85	3.93	0.68
	CSP3	0.65	3.58	0.70
Expressive service performance	ESP1	0.77	3.92	0.68
(AVE=0.61, α=0.85)	ESP2	0.77	3.71	0.68
	ESP3	0.81	3.78	0.73
Collaborative service performance	CBSP1	0.75	3.79	0.72
(AVE=0.53, α=0.81)	CBSP5	0.74	3.83	0.69
	CBSP6	0.70	3.67	0.64
Relationship quality				
Customer trust in relationship	CT1	0.81	3.47	0.72
(AVE=0.65, α=0.89)	CT2	0.80	3.64	0.80
	CT3	0.82	3.54	0.78
	CT4	0.81	3.36	0.72
Customer satisfaction in relationship	CS1	0.84	3.94	0.59
(AVE=0.58, α=0.85)	CS2	0.76	3.87	0.67
	CS3	0.69	3.79	0.65
	CS4	0.72	3.60	0.72
Customer commitment in relationship	CC1	0.76	3.39	0.74
(AVE=0.58, α=0.81)	CC2	0.76	3.04	0.81
Repurchase intentions	RI1	0.76	3.67	0.67
(AVE=0.53, α=0.80)	RI2	0.72	3.38	0.68
	RI3	0.71	3.28	0.72

Furthermore, all three dimensions of service performance had significant positive impacts on relationship performance, which supports H1 (β=0.16, p<0.01), H2 (β=0.23, p<0.01), and H3 (β=0.30, p<0.001) respectively. According to the Chow test (Chow, 1960), the independent variable with a greater coefficient also has greater impacts on the dependent variable. Based on the coefficients, collaborative service performance plays a greater role in relationship performance than competence-based service performance and expressive service performance.

To test H5-H7, involving the mediated influences of three dimensions of service performance on customer repurchase intentions, an adapted version of Baron and Kenny (1986) procedure was applied following Briggs and Grisaffe (2010). Four conditions are required to support full mediation. First, the independent variable must significantly affect the mediator. Second, the mediator must significantly affect the dependent variable. Third, the independent variable must significantly influence the dependent variable when the mediator is removed from the model. Last, for full mediation to be supported, the direct path from the independent variable to the dependent variable must become non-significant when the mediator is returned

Table 3. Discriminant Validity Test from Average Variance Extracted

Construct	1	2	3	4	5	6	7
1. Competence-based service performance	**0.62**						
2. Expressive service performance	0.38**	**0.61**					
3. Collaborative service performance	0.36**	0.50**	**0.53**				
4. Customer trust in relationship	0.39**	0.45**	0.44**	**0.65**			
5. Customer satisfaction in relationship	0.42**	0.48**	0.47**	0.48**	**0.58**		
6. Customer commitment in relationship	0.02*	0.09**	0.11**	0.10**	0.08**	**0.58**	
7. Repurchase intentions	0.13**	0.20**	0.24**	0.23**	0.32**	0.21**	**0.53**

Note: *p<0.05, **p<0.01
The bold diagonal entries show the average variance extracted by the construct, while the off-diagonal entries show the squared correlation between constructs. Source: Fornell & Larcker (1981)

to the model. Therefore, model 1 was estimated to test the first two conditions, model 2 was estimated to test the third condition, and model 3 was estimated to test the final condition.

In model 2, the direct effect of competence-based service performance on repurchase intentions was not significant (β=0.07, p>0.05). Therefore, it did not meet the third condition of full mediation, rejecting H5. In terms of H6, all four conditions were supported. Model 1 demonstrated that expressive service performance has significant impacts on relationship performance and that relationship performance has significant impacts on customer repurchase intentions. Model 2 confirmed that the direct path from expressive service performance to customer repurchase intentions is significant and positive (β=0.11, p<0.05), when the path from relationship performance to repurchase intentions is constrained to be zero, supporting the third condition.

Our analysis of the Model 3 revealed that the direct path from expressive service performance to repurchase intentions becomes non-significant (β=0.05, p>0.05) when the influences of relationship performance were inserted back into the model. These findings confirm that relationship performance fully mediates the relationship between expressive service performance and customer repurchase intentions, confirming H6. As for H7, all four conditions were also supported. Model 1 represented that the first two conditions were met. Model 2 confirmed that the direct path from collaborative service performance to customer repurchase intentions is significant and positive (β=0.36, p<0.01), when the path from relationship performance to repurchase intentions is constrained to be zero, supporting the third condition. Model 3 found that the direct path from collaborative service performance to repurchase intentions becomes non-significant (β=0.15, p>0.05) when the influences of relationship performance were inserted back into the model. Collectively, these findings confirm that relationship performance fully mediates the relationship between collaborative service performance and customer repurchase intentions, confirming H7.

5. Discussion and Conclusions

Extending the explanatory power of service performance theories beyond their original B2C service contexts into analyzing the B2B services calls for further investigations that consider the combined effects of various service dimensions on service performance in the customer-provider relationship, and ultimately, on customers' repurchase intentions. This study is among the first to examine how both service performance and relationship performance influence repurchase intentions in B2B services. The data covers a wide range of industries, thereby supplementing the pre-existing studies that have focused on specific sectors and phases in buyer decision making (Bolton et al., 2006).

5.1 Theoretical implications

Empirical research examining buyer-supplier relationship performance in B2B contexts has often

Table 4. Descriptive statistics of the sample

Respondent position	Purchasing function	Other function	N	Share
Executive	4	7	11	7.8%
SVP or VP	9	1	10	7.09%
Director	28	4	32	22.70%
Manager or Team leader	62	3	65	46.1%
Expert, Specialist or	17	5	22	15.6%
Assistant or Coordinator	1	0	1	0.71%
Total	121	20	141	100%
Average purchasing experience (years)	12.8	13.8	12.9	

Industry	Number of respondents	Percentage
Manufacturing	51	36.17 %
Health care and social assistance	14	9.93 %
Information (publishing, telecommunications, all	13	9.22 %
Professional, scientific and technical services	13	9.22 %
Other services (except public administration)	11	7.80 %
Retail trade	6	4.26 %
Accommodation and food services	5	3.55 %
Utilities (power, gas, water, sewage, etc.)	5	3.55 %
Agriculture, forestry, fishing and hunting	4	2.84 %
Finance and insurance	4	2.84 %
Transportation and warehousing	4	2.84 %
Mining, quarrying and oil and gas extraction	3	2.13 %
Construction	2	1.42 %
Educational services	2	1.42 %
Public administration	2	1.42 %
Real estate and rental and leasing	1	0.71 %
Wholesale trade	1	0.71%
Total (17)	141	100%

considered service performance as an aggregate construct (Arnott et al., 2007; Briggs & Grisaffe, 2010). By investigating the three dimensions of service performance - competence-based, expressive, and collaborative - this study found that all three dimensions directly impact relationship performance. This finding demonstrates that the service outcome, the customer's affective reactions, and the collaboration between the customer and their provider during service exchanges are essential in business service exchanges. Compared with competence-based service performance, expressive and collaborative service performance have more substantial effects on business relationships, emphasizing the importance of the service experience as a critical determinant in building inter-organizational relationships. This is consistent with previous studies which demonstrate the value of investing in "soft" services (Chatterjee, 2017).

This result contradicts the finding by Chumpitaz Caceres & Paparoidamis (2007), which indicated a greater effect of the technical service quality on the relationship satisfaction as compared with the functional service quality. Potential explanations for this include that the complexity of services in the current study might be higher than previously studied, as the growing trend of purchasing business services has become more complex in the markets (Selviaridis et al., 2013). Complexity arises from the diversity of interaction between parties involved in the service delivery, uncertainties of the situation in which the service takes place, and difficulties in evaluating service outcomes (Zou et al., 2018). The increasing level of services complexity is reflected in the supporting processes and resources required, which eventually increases complexity in contemporary business relationships. This indicates a growing importance for collaborative service performance in complex B2B services.

Moreover, the analysis provides an empirical explanation for the supplier selection and continuance rationale of purchasing business services. Similar implications were provided in an earlier study by Lindberg & Nordin (2008), who demonstrated that the choice of service provider involving complex services is based on "soft" factors, such as the supplier's responsiveness, flexibility, creativity, and ability to co-operate. These factors are consistent with expressive

Table 5. Standardized Estimates and Fit Indices for Structural Equation Modeling

	Model 1		Model 2		Model 3	
	Co-efficient	Z-value	Co-efficient	Z-value	Co-efficient	Z-value
Estimated path						
Competence-based service performance -> relationship performance	0.16**	2.62	0.16**	2.62	0.16**	2.62
Expressive service performance -> relationship performance	0.23**	2.93	0.23**	2.93	0.23**	2.93
Collaborative service performance -> relationship performance	0.30***	3.70	0.30***	3.70	0.30***	4.32
Competence-based service performance -> Repurchase intentions			0.07	0.78	-0.04	-0.45
Expressive service performance -> Repurchase intentions			0.11*	2.04	0.05	0.44
Collaborative service performance -> Repurchase intentions			0.36**	2.87	0.15	1.28
Relationship quality -> Repurchase intentions	0.75***	9.66			0.70***	6.04
Fit indices						
CFI	1.00		0.96		1.00	
TLI	1.02		0.91		1.00	
RMSEA	0.00		0.04		0.00	
X2/(df)	0.62(2)		10.74(3)		0.02(1)	
CD	0.55		0.61		0.56	

Note: *p<0.05, **p<0.01, *** p<0.001

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and collaborative service performance in this study. Purchasing complex services require continuous interaction and flexibility between the parties, which thus implies the importance of "soft" criteria in supplier selection criteria.

Our analysis revealed that the link between expressive service performance and customer repurchase intentions is fully mediated by relationship performance. Compared with prior findings in B2C contexts, the B2B context appeared to weaken the direct influence of expressive service performance on customer repurchase intentions, while strengthening the indirect impact by generating a mediating role for relationship performance. Customer repurchase intentions depend on the relationship with service providers, rather than emanating directly from expressive service performance. The study also confirmed that relationship performance mediates the relationship between collaborative service performance and customer repurchase intentions. This implies that good inter-organizational relationships are "order qualifiers" for repurchase intentions, whereas strong collaborative service performance represents a potential "order winner".

The recent megatrends in business, such as business process outsourcing (Handley & Benton Jr., 2009), servitization of product-based businesses (Rajala et al., 2019), the increasing complexity of product services systems (PSS), and the emergence of digital platforms for business, have led to the proliferation and spreading of B2B services beyond traditional service sectors. Service performance has been considered a key contributor to business continuity (Zeithaml et al., 1996), warranting further considerations due to complexity increases to B2B services in recent years (Zou et al., 2018).

The present study adds to current knowledge by having identified and analyzed the influence of three dimensions of service performance on relationship performance and customer repurchase intentions in B2B contexts. Expressive and collaborative service performance were shown to be the dominant determinants for successful buyer-supplier relationships. These performance dimensions ultimately translate into customer repurchase intentions through the mediating role of relationship performance. Hence, despite the quite mature discussion on service performance in the literature, this study increases understanding about the determinants of service purchasing decisions in B2B contexts.

5.2 Managerial implications

This study offers three practical implications for B2B service exchanges. First, the results suggest that investing in expressive and collaborative service performance is likely to pay off for business continuity. Here, the use of design tools to focus on customer emotions during service delivery (Beltagui & Candi, 2018) and improve information flow between parties (Barratt, 2004) could be helpful. To cultivate good business relationships with customers, service providers should train service employees on how to deliver services. Service managers can develop ways of interacting with customers to understand their needs better and to monitor and adapt to changes in service delivery.

Second, the impact of mediation implies that relationship performance is indispensable to reap the results from good service performance as a way of maintaining long-term business continuity. This provides strategic guidance for service companies to allocate their resources to both service improvements and relationship management, while ensuring that their companies' service strategies are not solely based on principles that apply to B2C contexts.

Finally, the findings have implications for organizational buyers. If a purchasing organization desires long-term partnerships with their service provider, especially in complex services, purchasing managers should give more weight to "soft" indicators. Although "soft" criteria may seem particularly difficult to evaluate, buyers can assess provider capabilities based on references and feedback from previous customers.

5.3 Limitations and avenues for future research

While the findings are robust, the study has certain limitations that suggest a direction for future research. First, in survey development, the wording and contextual fit of the scale items were examined in interviews and pre-tests. Given that the questionnaire was administered globally, purchasing professionals in different countries might have interpreted the behaviour-related questions differently. Therefore, studies in a global research context should invite people from different countries to further test the questionnaire.

Second, due to the type of dataset, the results need to be interpreted with caution. Although the 1,000 people on the contact list were randomly selected from two purchasing groups on LinkedIn, membership in these purchasing groups are not random. The collected data covered 17 industries from 23 countries, though the distribution of sectors was not equally represented, making generalizability across all industries uncertain. Future studies should examine the research model using a larger and more comprehensive sample, including more equal distribution of various sectors and countries. This would also allow further comparison of results from multiple industries, thereby improving our understanding of making service repurchasing decisions in different organizations.

Finally, future research should introduce control variables into the research model. Variables such as company size and age of relationship may be necessary for B2B service contexts and could help eliminate or explain other possible effects on customer intentions.

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Ecosystems, Design, and Glocalization: A multi-level study of Technovation

Jasmine A. Shaw & Steven M. Muegge

"*Business ecosystems form around problems to solve and pain to soothe.*"

James F. Moore
Management scientist, coined "business ecosystems"

Business ecosystems are an increasingly prominent organizational form in both management research and practice. A growing body of research exists about ecosystem design, but designing local ecosystem instances within a global ecosystem is not yet well understood or defined. This article contributes a multilevel, embedded case study of the global and local ecosystems anchored around the *Technovation* Girls competition — the world's largest technology entrepreneurship challenge for girls. We first define the process platform driving this ecosystem and anchoring the local instances. Second, we identify key architectural properties of a global-local ecosystem. Lastly, we specify a process for defining design rules in an organizational setting. In addition to theoretical relevance for ecosystem scholarship, our results are also of practical relevance to leaders of existing or nascent global ecosystems, who may benefit from techniques described in this paper that involve designing a flexible global ecosystem architecture that accommodates local variation.

Introduction

Business ecosystems are prominent in both theory and practice. What began as an ecological metaphor (Moore, 1993) has now become an organizational form (Moore, 2006) for the complex social systems that drive product development, innovation, and new venture creation (Adner, 2017; Muegge & Mezen, 2017; Kapoor, 2018; Muegge et al. 2018). Nonetheless, much work yet remains. Ecosystems as organizational forms for social impact through non-profit organizations have not received much attention, while the structures of global ecosystems with local embedded instances remain largely or entirely unexamined.

To explore how local variants of a global ecosystem are designed, this study brings together two management constructs from adjacent streams of management research. First, we look at *design rules*, as enforced system parameters that preside at the highest level of a system's architecture (Baldwin & Clark, 2000). These parameters "affect other parameter choices but they themselves cannot be changed". Second is *glocalization*, which describes the co-developing and mutually reinforcing interactions between global and local entities (Drori et al., 2014). According to glocalization theory, organizations face the "simultaneity and interdependence of particularizing and universalizing tendencies", with the global tending towards "universal", and the local tending towards "particular".

Business ecosystem research has contributed multiple frameworks, with no single framework yet emerging as dominating discourse. For example, the multisided platform perspective has been used to characterize the Lead to Win (Bailetti & Bot, 2013; Sunna, 2016; Muegge & Mezaen, 2017) and Intel (Gawer & Cusumano, 2014) ecosystems. Adner (2017) developed a structural framework to identify the interdependent connections between actors in an ecosystem. Integrating several dimensions from the literature, Rong et al. (2015) constructed a "6C" framework, and applied it to companies engaged in the Internet-of-Things ecosystem. Others describe ecosystems as "multi-level systems" (Muegge, 2011a; Muegge, 2013).

Within this body of research, scholars have identified the need to extend their focus beyond a single ecosystem perspective. This study thus attempts to close two knowledge gaps. First, this is the lack of understanding of the multi-level architecture of embedded ecosystems (Radziwon & Bogers, 2019). Second, this is the lack of knowledge on the application of process platforms in

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different field settings (Muegge et al., 2018), that is, “mission-driven” rather than “product-driven” ecosystems.

This research examines the network of individuals and organizations anchored around *Technovation* (https://www.technovation.org/), a non-profit education technology organization. Technovation’s flagship program, *Technovation* Girls (https://technovationchallenge.org/), is the world’s largest technology entrepreneurship competition for girls. We address the following research questions: *What is Technovation, and can it be described using frameworks from the business ecosystem literature?* and *What are the design rules for local Technovation chapters?* Our case study encompasses six local Technovation chapters — three in Canada, and three in Mexico —operating under the umbrella of the non-profit parent organization. As the country of residence of both researchers, Canada was chosen for both familiarity and access to key informants. Mexico was chosen for theoretical replication: its cultural dimensions vary widely from Canada’s, and their Technovation program is structured differently at the national level.

Technovation was chosen as the field setting for three reasons. First, it is a novel organizational setting. Rather than creating new ventures or innovative products, Technovation leverages the ecosystem setting to create intangible social goods such as entrepreneurial opportunity and self-efficacy. Second, it is an exemplary case. Since its inception, over 25,000 students have participated in the Technovation Girls program. Third, gender equity is a United Nations Sustainable Development Goal (https://sdgs.un.org/goals/goal5) that is front and centre on the global stage. Furthermore, in the Science, Technology, Engineering, and Math (STEM) domain, there is an even greater disparity of female representation. In 2014, a paltry 19% of engineering students in Canada were women (Natural Sciences and Engineering Research Council of Canada, 2017).

There are three primary contributions of this research. First is specification of the global Technovation ecosystem. Explicitly articulating the components and processes of a program designed to empower girls through technology entrepreneurship can support other organizations striving towards the same goal. Second is an exploration of the architectural properties of a “glocal” ecosystem. Third is a process to specify design rules for an organization and provide representative examples. This process can be directly applied by managers seeking to bound the variation and adaptation of local subsidiaries.

This article is organized into six sections. Section 2 presents key information from prior studies on business ecosystems, design science and design rules, and glocalization. Section 3 describes the research method used. Section 4 presents the research results, which are further elaborated in Section 5. Section 6 concludes with key insights and opportunities for future research.

Literature Review

This literature review summarizes and interprets prior research on business ecosystems, glocalization, and design rules.

Business ecosystems

Business ecosystem research initially stemmed from a biology-based ecological metaphor: a firm as an entity whose “survival” is determined by its “co-evolution” with fellow species such as suppliers, partners, customers, and competitors, to name a few (Moore, 1993). Within a business ecosystem, these entities have complex, interdependent relationships, that includes both competing and collaborating with one another to achieve a shared purpose (Moore, 2013) or focal value proposition (Adner, 2017; Kapoor, 2018). In contrast with biology-based ecosystems, in technology-based business ecosystems the shared purpose is driven by “a set of values about openness of ideas and technologies” (Moore, 2013).

In a recent article exploring previous research in this domain, Kapoor (2018) distilled the core elements of a business ecosystem into *actors*, *activities*, and *architectures*. Each is explored below in further detail. *Actors* are the entities who participate in shaping the ecosystem’s shared purpose. While early studies equated actors to firms (Moore, 1993; Iansiti & Levien, 2004), recent literature has acknowledged that the ecosystem construct extends beyond the product development space. These new perspectives encompass actors such as universities, and economic development agencies, as well as individuals. Regardless of who they are, participation within an ecosystem involves *interdependence*, meaning that each actor’s individual contributions “share in some large measure the outcome of the whole ecosystem” (Muegge, 2011a). A leader or *keystone player* (Iansiti & Levien, 2004) often emerges to develop the overall vision and strategy for the ecosystem.

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Activities are the "discrete actions to be undertaken in order for the value proposition to materialize" (Adner, 2017). For entrepreneurial ecosystems, incubation and acceleration (Colombelli et al., 2017) and providing capital funding (Bailetti & Bot, 2013) are key contributions. Meanwhile, in a traditional business ecosystem, delivering a specialized technology or defining a technological solution architecture are common contributions (Iansiti & Levien, 2004).

Last is the ecosystem's *architecture*, which defines the structural configuration of actors and activities required to achieve a shared purpose. Simply put, it is what "connect[s] offers and actors" (Kapoor, 2018). In addition to the existence of an architecture, Adner (2017) argues that actors must agree on their relative position within this configuration. Agreement by all actors creates *alignment*, which in turn reduces the risks associated with ecosystem-driven development. Another key feature impacting architecture is the anchor: a technical, organizational, or social entity connecting actors in the ecosystem, and often responsible for forming its boundaries (Muegge, 2011b)

Ecosystem architecture has been represented by multiple frameworks. One of the most common representations is the *multisided platform*. A platform is "a set of technological building blocks and complementary assets that companies and individuals can use and consume to develop complementary products, technologies, and services" (Muegge, 2011a). A multisided platform is a configuration of stakeholders, or *sides*, who transact through the platform. An alternative architectural representation is the *multi-level system*, comprised of three organizational levels: an ecosystem, community, and platform (Muegge, 2013; Muegge & Mezen, 2017). Yet another perspective is governance design, which considers networks of actors, that exchange information and enable learning processes (Colombelli et al., 2017).

Applications of the ecosystem construct have expanded well beyond the original realm of product development. However, ecosystems anchored by a non-profit organization, whose shared purpose is social good, have yet to be studied empirically. To characterize the focal organization of our study, we selected the multisided platform perspective, for two reasons. First, our initial review of Technovation's organizational structure revealed several stakeholder groups, which suggested the presence of "sides". Second, it has been successfully used to characterize "non-traditional" ecosystems, such as those anchored by venture-creation processes.

Design

Consistent with prior work on ecosystem design by Muegge et al. (2018), our research positions business ecosystems as *design artifacts*. In general, artifacts have an architecture comprised of components (Simon, 1962). The components may be nested within other components or arranged horizontally at the same level. This structural arrangement is called a *hierarchy*. When components are organized such that there is interdependence within and independence across (Baldwin & Clark, 2000), the design is considered *modular*. According to Parnas (1972), modularity can be achieved through information hiding, whereby each module possesses "knowledge of a design decision which it hides from all others".

A modular design is key to the growth of platforms because it increases potential for complementary innovation (Gawer & Cusumano, 2014). With clearly defined interfaces, modules can easily be swapped in and out of the platform. Additional modules increase traffic through the platform, thus increasing its value through network effects. Modularity is also a prerequisite condition for *option value*, "the right but not the obligation to choose a course of action" (Baldwin & Clark, 2006). In the context of a platform, option value allows complementors the opportunity to plug in their module without undercutting the functionality of the system as a whole.

In a modular system, *design rules* are parameters which preside at the highest level of the system —that is, they represent visible information (Baldwin & Clark, 2000). By converting an ordinary design parameter into a design rule, interdependency gets replaced with hierarchy. Iterative design which would normally occur in an interdependent structure is now governed by a fixed parameter. Although new design rules may emerge as interdependencies become apparent, rescinding design rules well into the design process can be costly, because these rules impact all lower-level modules. As such, the architects who specify design rules often have first-hand experience working with complex systems, which helps them to anticipate latent interdependencies.

Baldwin and Clark, define three types of design rules: *architectural*, which specify "what modules will be part of the system, and what their roles will be"; *interface*, which specify "descriptions of how the different modules will interact"; and *integration*, or "procedures that will allow designers to assemble the system and determine how well it works" (2000).

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The design rules construct is inherently multi-level. It describes "global" parameters that influence the design of "local" modules. The points of similarity between design rules and glocalization, as seen in the next stream below, are central to our subsequent analysis.

Glocalization

Our review of the business ecosystem literature located no studies that had examined the instantiation of regional instances within a global ecosystem. Thus, we turned to the glocalization literature to explore the underlying theoretical constructs of multinational organizations.

Robertson (1995) presented glocalization as an alternative theoretical perspective to globalization. He argued that the "debate about global homogenization versus heterogenization should be transcended". Rather, glocalization stipulates that global and local phenomena co-exist and influence one another. Drori et al. (2014) also argued that, in practice, the universality-particularity dichotomy is insufficient: "Multinational organizations wrestle with matters of identity and of operations that are simultaneously global and local". Thus, real-life decisions cannot be categorized as one or the other: real decisions fall somewhere between.

In the transfer from global to local, designed artifacts pass through an adaptation process to bring them into alignment with local values and culture. This re-contextualization does not completely sever the localized form from its global ancestor. It retains a "family resemblance with all the other localized variants that accounts for the underlying universalizing dimension" (Meyer, 2014). Subsidiaries are instances of a multinational corporation that make up the system (organization) as a whole. Similarly, modules are complementary, unique units of a platform.

Method

Our research followed Yin's (2018) case study method, employing an embedded, multi-level design. The context was the 2020 Technovation Girls season (a four-month long competition), and the phenomena were 7 cases: 1 global non-profit organization along with 6 local chapters. The chapters were based in Ottawa (Canada), Montréal (Canada), Calgary (Canada), Guadalajara (Mexico), Mexico City (Mexico), and Mérida (Mexico). To describe and explain the design of local ecosystems operating within the context of a global technology entrepreneurship competition for girls, we used the techniques of previous studies for mapping business ecosystems (Mezen, 2014; Sunna, 2016), in particular the multisided platform representation (Table 1).

Data collection was carried out by the first author between January and May 2020. This included interviews with 26 stakeholders: global stakeholders included employees and Board of Directors members, while local stakeholders included regional ambassadors, a subset of volunteers (mentors, judges, and instructors), and representatives from partner organizations. Direct observation and participant-observation included Technovation events: orientation meetings, workshops, competitions. Archival sources included online news publications and social media postings from each of the six local chapters, the Technovation website, including the Technovation Girls FAQ (https://iridescentsupport.zendesk.com/hc/en-us/categories/115000091348-Technovation-Girls), and a documentary film about the Technovation Girls

Table 1. Multisided platform ecosystem framework

Feature	*Explanation of feature*	*Sources*
Sides	Platform sides Characteristics of side	Muegge et al. (2018) Sunna (2016)
Platform	Processes Components/sub-components	
Controls	Contractual terms of direct interaction Openness	
Desired outcomes	Membership rules for each side System-level objectives	

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Table 2. Multisided platform representation of Technovation

Feature	*Technovation Global explanation of features*
Sides	• 10 sides defined in Table 3 • Contributions and expected benefits defined in Table 3
Platform	• A cyclical process shown in Figure 1 • 6 components and 19 sub-components defined in Table 4
Controls	• Some transactions are mediated through Technovation digital platform • Global organization does not constrain interactions of local actors • Membership rules for platform sides defined by eligibility criteria
Desired outcomes	• Increased self-efficacy in participants • Participants electing to pursue studies in STEM disciplines

competition (http://www.codegirlmovie.com/).

Our analytic strategies were cross-case comparison (Eisenhardt, 1989; Miles et al. 2014) and explanation-building (Yin, 2018). We imported our data into NVivo qualitative data analysis (QDA) software and coded the text according to key themes derived from our research questions, our guiding frameworks, and the prior literature. We used the coded data to populate a table describing the constructs and parameters of the ecosystem framework, and to specify the platform and its components. Comparing cases, we inferred design rules for local Technovation chapters.

Results

The global Technovation ecosystem was characterized as a multisided platform, shown in Table 2, which maps the core ecosystem features to Technovation elements.

The ten sides are distinguished by their stakeholder group roles in the ecosystem. The actors on each side undertake unique activities that provide unique contributions. Some of the sides are official roles within the Technovation Girls competition, whereas others were identified through interviews with key personnel. For example, the “influencers and community leaders” side is not a role that an individual would formally register for; nonetheless, the actors on this platform side make an important contribution by helping new chapters gain legitimacy in their region.

Table 3 (placed at the end of this document) describes the multisided platform sides represented in Technovation. Sides 1 through 5 operate at the global level, while sides 6 through 10 operate within the local chapters. The local chapters are further decomposed into their own representations; however, collectively, all are connected through the global ecosystem.

The Technovation platform is driven by a *process* (Figure 1). The process is comprised of components, meaning the elements of the Technovation program that drive execution.

Some aspects of the process that we observed were tightly controlled by Technovation. For example, program registration and final project submission are mandated through their digital platform. Other platform transactions, such as curriculum delivery to students, were not specified globally. Further, only select platform sides had prescribed membership rules: volunteers, participants, and student ambassadors. Participation by other stakeholders was elective, based on self-alignment to a shared purpose.

Lastly, desired outcomes were focused on ensuring the program had a lasting, positive impact on participants

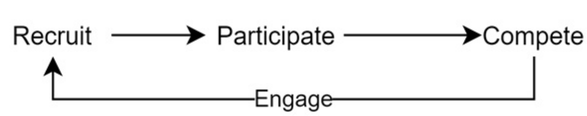

Figure 1. Technovation process

and their future careers. Achieving these outcomes was the shared purpose (Moore, 2013) of the ecosystem.

Local adaptation
The ecosystem mapping approach was repeated for each of the six chapters. A notable result was that not all platform sides directly translated to the local level. For example, employees and the global ambassador were not present locally. On the other hand, the volunteers platform side was expanded to *multiple, separate sides* for regional ambassadors, mentors, judges, and instructors. New roles also emerged, such as schools and clubs. Furthermore, the particular stakeholders that comprised the platform sides, both individuals and organizations, varied between chapters.

The process platform was adopted consistently across all chapters. However, implementation of its components varied. For example, the Calgary chapter delivered program workshops (part of the "participate" process step) through secondary schools and the University of Calgary, while in Ottawa, workshops were delivered through corporate partners. For the "compete" process step, the Mexican chapters held individual live pitch events, whereas the Canadian chapters combined it into a nation-wide event.

Controls between platform sides varied based on requirements imposed by the regional ambassador or partner institutions. For example, one chapter required all male mentors to communicate with participants only through public channels. In another chapter, the regional ambassador was not permitted to directly match students with a mentor due to institutional liability it imposed on them.

Lastly, desired outcomes of the global ecosystem were translated to and shared among the local chapters. Certain chapters had additional, region-specific objectives, such as expanding the program throughout the province (Montréal), increasing engagement from both private and public sector volunteers (Ottawa), and raising awareness of career opportunities in non-traditional fields (Mérida).

Design rules
Consistent with Baldwin and Clark (2000), we identified and specified a design rule for each mandatory element of the various multisided platforms.

The process for specifying design rules within Technovation can be described in five steps: (1) identify mandatory program elements, (2) confirm the implicated actor is aware of a specific design rule (i.e., it is "visible information"), (3) express the rule using natural language, (4) identify one example for each design rule type consistent with the Baldwin and Clark (2000) definitions, and categorize the remaining design rules relative to the representative example, and (5) cross-reference design rules with program components to identify any gaps. Not all components necessarily have an associated design rule.

We present three examples of design rules corresponding to the three Baldwin and Clark (2000) types. First, architectural design rules define mandatory platform elements. They describe "who" and "what" is part of the system for it to function. One example is: *Individuals must meet criteria for mentors to volunteer as a mentor for Technovation Girls.* Second, interface design rules described the interactions (between individual sides as well as between the sides and the platform) and the interpretation and standardization of platform components. An example is: *Teams must use one of the approved coding languages if they wish to be eligible for judging in the Technovation Girls competition.* Lastly, integration rules ensure the program's consistency and efficacy. For example: *Each Technovation Girls chapter must comply with the Technovation branding guidelines.* Creating a familial resemblance among chapters has become particularly important strategically as they span over 50 countries, with a set of branding guidelines ensures that the regional instances remain part of the overall system.

Discussion

Our results imply three key insights about the architecture of global ecosystems.

The first insight concerns ecosystem anchors. Actors at the global level are largely focused on scaling up the Technovation program and increasing its global impact. This is accomplished through standardized processes developed by employees, strategic guidance by the board of directors, and international expansion led by the global ambassador. Global actors are thus anchored by *shared purpose*. Actors at the local level also share the objective of supporting girls in STEM, but they are anchored by a process (Figure 1). Local participation is bound to the Technovation Girls competition, whereas global participation is continuous and extends beyond a single competition cycle. However, the local chapters and global ecosystem are not detached entities following divergent paths. The non-profit organization is the keystone actor who mediates between these two levels

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and ensures alignment between high-level vision and strategy, and low-level program execution. Thus, we propose a *multilevel anchor* model (Figure 2).

The second insight concerns platform adaptation. The process steps served as a framework for local adaptation, which was performed at the *component* level. We observed both modularity and option value embedded in the platform. For example, the curriculum component is comprised of lessons (that is, individual modules), which the chapters reconfigured in various sequences. Further, the platform did not mandate participation in the *compete* and *re-engage* stages of the process. This created option value, whereby students and volunteers could participate as little or much in the program as they wanted. In the 2020 season, some teams did not submit their final project due to COVID-19; however, their participation at the beginning of the season still provided value (learning new skills, exposure to role models, etc.).

Designing a program that accommodates cultural, social, and economic variance of over 50 countries would be an impossible feat. Instead, Technovation has designed a platform with "modular mix-and-match flexibility [that] creates options" (Baldwin & Clark, 2000). Based on Technovation's example, we propose that, in a global organization with regional instances, *modularity facilitates localization*.

The third insight concerns how design rules specified by Technovation create boundaries for local adaptation. Fixed parameters, such as limiting program participants to girls, have led to "a gain in efficiency through the elimination of cycles in the design process" (Baldwin & Clark, 2000). That is, local chapters do not waste time on debating whether boys should be allowed to participate. Similarly, students developing their mobile app are limited to a predefined set of coding languages. While these fixed parameters constrain certain design decisions, their flexibility further increases the option value of the program: organizers may recruit girls from any part of their community, students may select any of the approved coding languages, and volunteers may come from a variety of professional backgrounds. This finding is consistent with the Meyer (2014) assertion that "glocalization supports local variations, but within legitimated boundaries" as well as with Baldwin and Clark (2016), according to whom "modules are distinct parts of the larger system, which can be designed and implemented independently as long as they obey the design rules".

Our results and discussion offer three contributions to theory and practice. Our first contribution was to specify the global Technovation ecosystem — including its actors, processes, and components —offering insights into a highly successful STEM outreach program. With increasing demands for diverse talent, it is imperative to learn from organizations with a proven track record of increasing young peoples' propensity to choose a career in STEM. Our second contribution was to explain about the impact of platform design on glocalization. We highlighted key architectural features of an existing process platform that enables local specialization. Lastly, our third contribution was expressing global

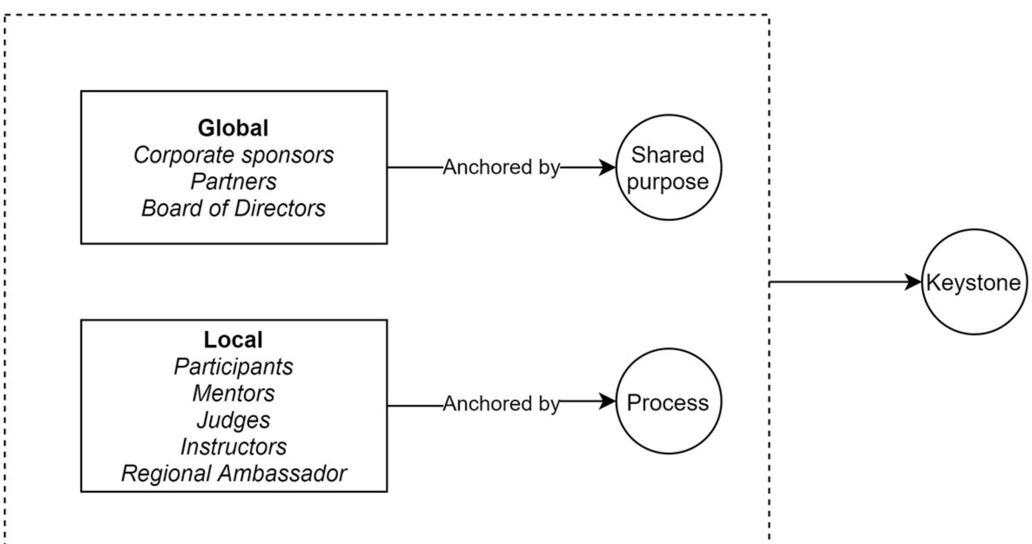

Figure 2. Multilevel anchor model of Technovation

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Technovation parameters as "design rules" —a novel approach in organizational studies. The five-step process defined in this study offers researchers and practitioners a method for characterizing interactions between global and local organizational entities, along with specifying those interactions as precise design rules.

We believe that the insights developed in this paper can spark further research. The process for deriving design rules can be validated in other organizational settings, such as a multinational corporation with local subsidiaries, or further extended within Technovation by examining additional regions beyond Canada and Mexico. Further, researchers should continue to explore multilevel ecosystems and refine the architectural propositions presented in this study, while developing a quantitative approach that expresses modularity and highlights the option value of process platforms.

Our research has three notable limitations. First, we focused on describing an established ecosystem. We did not observe the creation of either the Technovation process or its design rules. Thus, we may have missed out on deeper insights about how the design of a global ecosystem originated. Second, due to travel constraints imposed by COVID-19, we were not able to collect significant data in Mexico, which limited our understanding of how the three national chapters adapted the global platform. Lastly, we selected only a single framework to map Technovation. This inevitably created blind spots in our characterization of Technovation as an ecosystem, as we know that "each [framework provides] partial yet incomplete representations of the business ecosystem phenomena" (Muegge & Mezen, 2017).

Conclusion

Business ecosystem research has expanded from product development, to technological innovation, to entrepreneurial ecosystems, which in turn create new ecosystems. We have further extended the applicability of the ecosystem construct in this paper to a mission-driven, global non-profit organization. By combining design rules with glocalization, we demonstrated that local instances of a global ecosystem are governed similarly to a complex system. Local instances share common components that can be adapted locally within the boundaries of global design rules. Scholars and practitioners can build on this linkage between design rules and glocalization to further explore the architecture of global ecosystems.

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Appendix

Table 3. Platform sides of Technovation

#	*Stakeholder group*	*Participants*	*Contribution to the platform*	*Expected benefits from the platform*
1	Technovation employees	Individuals	Knowledge	Personal satisfaction Salary
2	Corporate sponsors	Google Adobe Salesforce (Organizations)	Sponsorship Credibility Volunteers	Employee engagement opportunity Corporate social responsibility alignment
3	Partners	TechWomen	Support Visibility	Direct impact to their programs
4	Global ambassador	Individual	Funding Political and industry support Regional updates and insights	Scaling the program globally
5	Board of directors	Technovation CEO Global ambassdaor Individuals from sponsor companies	Voluntary contribution of time and expertise Strategic guidance	Maintaining corporate engagement
6	Volunteers	Technology professionals Entrepreneurs Teachers	Time Resources Knowledge	Personal satisfaction Recognition
7	Participants	Girls aged 10-18	Time Dedication	Knowledge Positive experiences Increased confidence
8	Parents	Parents of participants	Support	Extracurricular opportunity for their child
9	Student ambassadors	Technovation alumni	Visibility Recruitment	Professional development opportunities
10	Influencers and community leaders		Enabling regional growth	Supporting women in STEM Security, credibility, and legacy of the program

Table 4. Technovation Global components

Technovation Global component	*Technovation Global element*
Program	Curriculum
	Digital platform
	World Summit pitch event
Regional ambassador resources	Resource page
	Webinars
	Technovation staff members (on-call support)
	Office hours
	Grants for regional programs
Volunteer resources	Webinars
	Resource page – mentors
	Resource page – judges
Participant resources	Support email
	Submission guidelines
	Rubric
	Code checklist
Alumni program	Professional development opportunities
	Alumni coordinator support role
Network	Slack channels
	Social media engagement

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Ecosystems, Design, and Glocalization: A multi-level study of Technovation

Jasmine A. Shaw & Steven M. Muegge

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Ecosystems, Design, and Glocalization: A multi-level study of Technovation

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Developing Social Impact Evaluation Methods for Research: viewpoints on commercialization and sustainability

Leena Kunttu, Helka Kalliomäki, Sorin Dan, Jari Kuusisto

“As highlighted by the OECD Innovation Strategy, better measurement of innovation and its impact on economic growth, sustainability and inclusiveness is key to fulfilling the promise of better co-ordinated innovation policies in the digital era.”

Angel Gurría,
OECD Oslo Manual, 2018

The social contributions of research activities have become more and more important in the rapidly changing innovation environment. Despite the fact that industrial commercialization of research results constitutes one of the most essential drivers for innovation and competitiveness, most generally used social impact evaluation criteria do not include clear metrics involving research commercialization possibilities. In a similar manner, principles regarding sustainable development have been largely omitted from the impact criteria. This paper considers the “broader impacts criteria” (BIC) model developed for social impact evaluation in the National Science Foundation in United States. We propose extensions to the BIC criteria related to commercialization and sustainable development viewpoints on impact evaluation. This paper also considers a newly introduced extension to BIC, called “inclusion-immediacy criteria” (IIC). Based on it, we propose an extended version of the model that aims to additionally evaluate the impact of research from commercialization point of view.

Introduction

Academic institutions are nowadays considered as important drivers for national economies, since they are expected to spur innovations and thus stimulate economic growth (Weckowska, 2015; Rajalo & Vadi, 2017). These benefits may be delivered by means of industry utilizing the results of the research made in universities. For this reason, governments and national innovation policy makers are actively promoting the establishment and development of collaborative networks between universities and society, represented by industry, other private sector actors, the public sector, and non-profit organizations (Morlacchi & Martin, 2009; Perkmann et al., 2013; Rajalo & Vadi, 2017). In this way, national innovation policies nowadays often emphasize a so-called “third mission of universities”, which means that in addition to the fundamental goals of higher education and academic research, universities are also expected to make social contributions. These social contributions may include collaborative knowledge creation, transfer, and exchange between universities and external partners (Pennacchio, 2016). Policy makers are thus increasingly expecting publicly funded research not only to produce scientific and scholarly results, but also to enable clear social impacts.

From the viewpoint of attempting to commercialize academic results, social impact now plays a central role. In this context, successful commercialization requires industrial firms to be able to absorb critical knowledge from universities, and together with university partners create new knowledge that may be critical for their future innovation and new product development (Kunttu & Neuvo, 2018, 2020). It has nevertheless been argued that the results of academic research seldom yield specific inventions or industrial products (D’Este & Patel 2007), while at the same time it has been difficult to empirically evaluate and show the direct impact of university collaboration on industrial innovation (Laursen & Salter, 2004).

In recent decades, methods and tools have been developed to evaluate the social impact of university/academic research. Since 1997, the National Science Foundation (NSF) in the United States of America has used specific evaluation criteria to assess the contribution of research to society by requiring grant applicants to discuss ways their research will have broader impacts on society. Since then, the so-called “broader impacts criteria” (BIC) has become a standard policy tool for the NSF to show policy makers and the public that government-funded research is useful from a social point of view. The BIC model requires researchers to show that their research makes a social contribution in terms of educational outreach or broad dissemination of results (also to non-academic audiences). The BIC model also highlights the collaboration with external stakeholders.

Woodson et al. (2021) have recently proposed an extension to BIC called "inclusion-immediacy criteria" (IIC). This model aims to determine how research impacts are distributed across various social groups. In the European Union's research funding instruments, the principles of "responsible research and innovation" (RRI) are used to evaluate the social contributions of research projects. RRI is used to evaluate the social impact of the research process by emphasizing viewpoints that involve ethical acceptability and ecological sustainability.

The existing general impact criteria such as BIC target evaluating the social impact of scientific research in general. Thus, these criteria do not consider impacts related to commercializing or developing innovations, which is often crucial to making the results of academic research useful for commercial products. In addition, the currently used version of BIC does not have links to sustainable development, which is considered one of the main themes in RRI. Likewise, the principles of sustainable development are strongly emphasized by the United Nations and its related organizations (Griggs, 2013).

In this paper, we discuss how the BIC model could be extended to better cover various aspects of commercialization and sustainable development. We also propose an extended version of the IIC model, which focuses on business and user viewpoints, both essential regarding commercialization. Both proposed extensions can be regarded as examples on how the currently used impact and evaluation criteria can be modified to meet the needs of commercializing academic research results.

The rest of the paper is organized as follows. Section 2 gives an overview of current assessments involving "social impact" and introduces the current BIC and IIC models. In section 3, we present our extended versions of these two criteria, and in section 4 discuss the contribution and conclusions of the proposed methods.

Literature Insights Assessing the Social Impact of Research

The priority of governments and innovation policy makers is to support research that not only increase scientific knowledge, but also contributes to society. For this reason, policy makers and other actors operating in the innovation policy domain have created policy tools that seek to evaluate the social impact of publicly funded research. In recent decades, connections between academic science and social impact have been emphasized in the national science policies, for example, in the USA and Europe. Behind this development are steady calls from politicians to make academic research more accountable, transparent, and applied, which has resulted in increasing demands from the public for demonstrable returns on investment in science (Woodson et al., 2021).

Broader impact criteria

In the USA, the National Science Foundation (NSF) introduced the broader impacts criteria (BIC) in 1997 to ensure that grant proposals would take the social impact of their research into account (Davis & Laas, 2014). BIC's European counterpart, Responsible Research and Innovation (RRI) was introduced in 2011, and has now been adopted into the European Commission's Horizon 2020 strategy. RRI has been defined as "a transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view on the (ethical) acceptability, sustainability and societal desirability of the innovation process and its marketable products (in order to allow a proper embedding of scientific and technological advances in our society)" (Burget et al., 2015). When comparing the BIC and RRI, it seems that BIC is concerned with more peripheral aspects of research that include, for example, inclusion and participation of disadvantaged groups, outreach activities and utilization of results. RRI, on the other hand, seeks to understand fundamental aspects about how research is conducted, including sustainability and equality considerations (Davis & Laas, 2014).

With pressure to increase the social contribution of science, both BIC and RRI have been relatively widely adopted as parts of impact evaluation systems. For example, both RRI and BIC offer guidelines on quite a general level, and there have been difficulties turning their general principles into specific guidelines (Davis & Laas, 2014). Debates have taken place about the importance and value of the BIC and RRI as evaluation methods (Woodson et al. 2021). Thus, there have been pressures to develop the current criteria to better respond to the needs of evaluating the wide practical social impact of academic research. Commercializing research results represents one essential part of these impacts (Perkmann et al., 2014). It also has been problematic that while a BIC-based evaluation is usually conducted, nevertheless the social impacts are often not systematically evaluated after the completion of the research projects (Woodson, 2021). Table 1 presents the BIC criteria that are used by evaluators of NSF grant proposals. The evaluators are asked to evaluate the social impact of the proposed projects based on these criteria.

Immediacy and inclusion

In recent years, there have been proposals to consider the immediacy of research. In Woodson et al. (2021), immediacy is defined as the inherent nature of broader impact activities relative to the research. Immediacy can be divided into three categories: intrinsic, direct, and extrinsic immediacy. Intrinsic immediacy refers to research activities that are central to the focus of a research project. Consequently, the goals of research projects that have intrinsic immediacy are directly related to the social impacts. Direct immediacy means impacts that are achieved while conducting the research, even if they are not the actual goals of the project. For example, training younger researchers and graduate students in education belong to this category. The third category is extrinsic immediacy. This means that project activities are separated from actual research, wherein the researchers make contributions to society through outreach activities such as school visits, public lectures, or newspaper columns. Table 2 summarizes the three levels of immediacy.

Table 1. BIC Criteria, adapted from Roberts (2009)

Criteria for Science	
Infrastructure for Science	Creation of new research methodology, tools, or data sources that will be useful to advance science
Broadening Participation	Recruiting or including under-represented groups in research or in outreach efforts. Involves efforts to attract women to science and to keep them in the academic pipeline for all fields, but excludes funding female students in biology and social sciences
Training and education	Includes mentoring undergraduates, graduate students, and postdoctoral fellows in the laboratory and teaching classes
Academic Collaboration	Research collaborations with other universities in the USA or abroad
K-12 Outreach	Outreach to kindergarten to 12th grade students or teachers helps to get kids excited about science and ensures a pipeline of future scientists. Note: in the USA, K-12 education is synonymous with primary and secondary education
Criteria for Society	
Potential Social Benefits	Direct claims that the research could help to inform policy, be useful for industry, or lead to some solution to a real-world problem. General statements of improved understanding of a natural or technical process (for example, climate change or ecosystems) were not included
Outreach/Broad Dissemination	Dissemination of research results for non-academic audiences in any form (web site, seminars, meetings, newspapers). Does not include K-12 outreach
Partnerships with Potential Users of Research Results	Includes partnerships with industry, non-profits, government bodies and national labs

Woodson (2021) has further developed this evaluation scheme by adding a new dimension “inclusion”, to better understand the role of various users of new innovations, including marginalized groups. Inclusion determines the types of people that benefit from the research. It is divided into three categories: universal, advantaged/status quo, and inclusive. Universal inclusion means that the innovation is targeted for everyone, independent of their status, and that everyone benefits from its results. For example, research related to minimizing the effects of climate change would belong to this category. Innovations in the second category primarily target advantaged groups, who can afford products based on innovation. New technological solutions for consumer electronics often belong to this category. These innovations may eventually also benefit marginalized groups, but only after being redesigned, or after advantaged groups have fully benefited from the innovation. The third category of inclusive innovations are those that are designed to help marginalized communities directly. Marginalization may be based on poverty or belonging to an underrepresented minority group, as well as a person’s dialect, gender identification, or religion. Thus, research initiatives with inclusive impacts may include, for example, the participation of women in scientific fields where they are underrepresented, or developing new pedagogical methods for children with special needs. Table 3 summarizes the levels of inclusion.

Table 2. Levels of Immediacy, adapted from Woodson (2021)

Levels of immediacy		Definition	Example
Intrinsic	1. Intrinsic immediacy	The activities are central to the research project	If researchers are developing a new solar panel, the BIs of producing clean energy are intrinsic to the grant
Direct	2. Direct immediacy	Activities that are achieved while conducting the research	The training of graduate students is not a goal of the research project, but it is still directly related to the research.
Extrinsic	3. Extrinsic immediacy	Activities are extrinsic to the actual project	If a researcher visits a secondary school to share the research results, then the activities are separate from the research and have extrinsic immediacy

In their newly proposed model: “Inclusion-Immediacy Criteria, IIC”, for assessing the social impact of research, Woodson et al. (2021) combined the immediacy and inclusion criteria. They suggest this combination complements the current BIC model by better determining how research impacts are distributed across social groups.

Research Method

In this paper, we extend the existing versions of BIC and IIC to highlight two distinctive themes: commercialization and sustainability. The reasons behind these proposed extensions are to underline the commercialization potential of research, and ensure that research takes into consideration demands related to sustainable development. Our research process started by making a review of the existing literature on impact evaluation with special emphasis on social impact.

We also benchmarked the most widely used evaluation approaches in the United States and Europe, namely BIC and RRI. These approaches were presented on quite a general level, and we identified several “blind spots”, that is, relevant areas that were not considered in the evaluations. Especially in the BIC approach, we found topics related to sustainable development and commercialization to be blind spots, since BIC had nothing related to sustainable development, and commercialization came across as quite vague.

Finally, we examined how these two topics could best be integrated with existing evaluation approaches. This led us to decide that the most straightforward way to do this would be to propose two new sections to the BIC model. In the following sections, we describe the practical process in detail.

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Table 3. Levels of Inclusion, adapted from Woodson (2021)

Inclusivity category		Definition	Example
Universal	1. Universal	Research targets everyone, regardless of status, i.e. the research is important to everyone and everyone benefits from the research.	Research to combat the effects of climate change
Advantaged/ Status quo	2. Advantaged / status Quo	Research primarily target advantaged groups and/or maintain the status quo. These innovations could eventually diffuse to marginalized communities, but only after they have been redesigned or after powerful groups have fully benefited from the innovation.	Research to design better watches and "smart" fabrics is primarily for powerful groups, like the military or wealthy consumers, who can afford that technology
Inclusive	3. Inclusive	Innovations that are designed to help marginalized communities directly	An inclusive activity might include increasing the participation of women in STEM fields or piloting new pedagogical approaches for children with special needs

Extending BIC and IIC models to cover commercialization and sustainability

Extending the BIC model with commercialization and sustainable development viewpoints

After an extensive preparation and inclusion process, the UN member states adopted 17 Sustainable Development Goals (SDGs) in 2015 (Griggs, 2013). These goals were based on an urgent call for action by all countries - developed and developing - in a global partnership towards peace and prosperity for people and the planet. The goals recognize that ending poverty and other deprivations must go hand-in-hand with strategies that improve health and education, reduce inequalities, and spur economic growth - all while tackling climate change and working to preserve our oceans and forests.

The European RRI framework relies strongly on these general UN goals in its principles for evaluating the social impact research. The current form of BIC has no dimensions related to sustainable development, despite the fact that demand for impacts related to green thinking, sustainability, wicked global problems, resilience, and equality are emphasized by the UN and many other global actors. For this reason, we propose two additional criteria to BIC, as presented in Table 4.

Commercializing innovations based on scientific research has been considered as one of the most essential social impacts of academic work. This is because commercialization and business development constitute immediate and measurable market impacts based on the results of academic research (Markman et al., 2008; Perkmann et al., 2013). The commercialization process is directly linked to developing new products or services. This creates commercial relevance for the firm that develop their businesses based on innovation. This means that the industrial interests to utilize research results are directly related to commercialization (Markman et al., 2008). Because the current form of BIC does not include criteria related to business development or the commercialization of results, we propose two additional criteria for commercializing, as shown in Table 5.

Developing a commercialization viewpoint to IIC model

As described earlier, the newly introduced model, "Inclusion-Immediacy Criteria" (IIC), was designed for

Table 4. Proposed new BIC criteria related to sustainability

Criteria for sustainability	
Green thinking	Does research consider the environment, climate change, and sustainability in the research process and results (green thinking)?
Resilience and global impacts	What kinds of impacts does the research have globally? Does research take resilience matters into account (e.g. anticipation to unexpected changes, like COVID-19)?

Table 5. Proposed new BIC criteria related to commercialization

Criteria for commercialization	
Business impact	What are the commercial and practical possibilities for using the research results in new products, services, and processes? Does the research factor in both expected and unexpected changes in the operational environment?
Impacts to users, customers, and consumers	How do the results affect individual users or consumers? How are users involved in the research and development? How are user inputs utilized?

assessing the social impact of research by combining criteria related to immediacy and inclusion (Woodson et al., 2021). The purpose of the IIC model is to complement the currently available BIC model by better determining how the impacts of research are distributed across social groups (see Table 2). In this paper we present an extended IIC criteria (EIIC) that focuses more on widespread social impacts involving three levels: universal, project stakeholder, and user. Based on this proposed model, social impacts related to practical usage and commercialization can be viewed and discussed within a wide scope, and evaluated in a systematic manner. In the EIIC model, the levels of immediacy remain the same as in the original IIC, whereas the modified inclusion levels of EIIC are summarized in Table 6.

The EIIC model can be presented as a 3x3 matrix, as shown in Table 7, where the rows represent inclusivity, while the columns represent immediacy. The first row is used to express the universal impact of research. It considers how research is important to everyone and how anyone can benefit from research. The intrinsic level of universal impact describes what direct goals of the project benefit everyone. For example, research that is directly related to reducing carbon emissions belongs to this area, since everyone benefits from having a cleaner environment. The direct level is used to describe the universal benefits achieved while conducting research (even if they are not a part of the project goals). For example, if a research project focuses on developing low-emission engine technologies, then a better environment is not a direct goal of the research, even while the results of the research could contribute to improving the environment. The extrinsic level of universal impacts includes those that are separate from the actual research. Outreach activities like school visits or podcasts to wide audiences belong in this category.

Table 6. The levels of inclusion in the original IIC (Woodson, 2021) and in the proposed EIIC model

Inclusion levels in IIC (Woodson, 2021)		Inclusion levels in Extended IIC (EIIC) proposal	
Universal	Universal (General societal impact) • Research targets everyone, regardless of status • The research is important to everyone and everyone benefits from the research.	Universal	Universal (General societal impact) • Research targets everyone • The research is important to everyone and everyone benefits from the research. • Sustainability considerations
Advantaged/ Status quo	Advantaged/Status quo • Research primarily target advantaged groups and/or maintain the status quo. • These innovations could eventually diffuse to marginalized communities, but only after they have been redesigned or after powerful groups have fully benefited from the innovation.		Impact to project stakeholders • Research impacts to the direct and indirect stakeholders of the project (funder, research institute, research communities, companies, ecosystems,...) • Business impacts
Inclusive	Inclusive (to marginal groups) • Innovations that are designed to help marginalized communities directly		Impact to consumers, users, and individuals • Impacts to individual people • User/consumer perspective • May include also specific impacts to the marginal groups

Table 7. Proposal of the extended IIC model (EIIC)

Immediacy / Inclusivity	Intrinsic	Direct	Extrinsic
Universal	Project activities that target to everyone's benefit directly	Project activities target to everyone's benefit but they are indirectly related to project coals	Activities that are not part of the project goals but can be beneficial to everyone
Stakeholders	How project goals directly benefit the stakeholders of the project?	How project goals indirectly benefit the stakeholders of the project?	Activities that are not part of the project goals but can be beneficial to stakeholders
Users	What are the direct benefits to the customers, users and consumers?	How the project indirectly benefit the customers, users and consumers?	Activities that are not part of the project goals but can be beneficial to users

The second row describes how the project benefits stakeholders. The stakeholders include both direct and indirect project stakeholders, such as funders, research communities, companies, public sector actors, ecosystems, etc. The impacts also concern business . The intrinsic level of stakeholder impact describes how a project's goals benefit the project's stakeholders, who can be regarded as customers of the research. The direct level of stakeholder impact expresses how the project's stakeholders may benefit from the research outside of its initial goals. For example, if a project develops new algorithms for an IT company (intrinsic result), a direct result might be having a competent R&D workforce trained during the project period, which can potentially be recruited by the customer company. The extrinsic level of stakeholder impact includes impacts that are separate from the actual research. For example, presentations given by researchers at events organized by stakeholder organizations belong in this category.

The third row in the EIIC matrix describes the impact of the research outcomes to potential users. This category considers how the end-users of research results, or the individuals somehow affected by the research results, are involved. As on previous rows, intrinsic impacts are direct outcomes from an end-user's point of view, and the direct impacts tell what kinds of benefits can occur while doing research. For example, research related to accessible and easy user interfaces causes intrinsic impacts to individual users. On the other hand, developing face recognition technologies aiming at new biometric solutions does not directly aim at consumer solutions, though the results may potentially end up in consumer photography applications. Extrinsic activities in the user category may be, for example, related to involving users or consumers in testing and evaluating newly developed innovations.

Discussion and Conclusion

As academic research makes contributions to society in many ways, it is important for funding bodies, policy makers and a general audience to understand the value of its social contribution. We considered this topic related to how the currently available impact evaluation approaches could better support commercializing the results of research. By developing dedicated evaluation approaches that emphasize commercialization, new possibilities arise to encourage the research community to pay more attention in considering applications for

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potential industrial usage of their research results.

In this paper, we also explored how sustainable development has a central role in the European RRI evaluation methodology. However, despite its growing importance, the principles of sustainability are absent in the American BIC evaluation concept. While the BIC criteria provide a good basis for assessing the social impact of funding proposals, they still lack important areas from the viewpoints of sustainable development and commercialization, both of which have become important themes for the social contribution of research. Because European RRI relies quite heavily on the principles of sustainable development, it would be beneficial also to BIC-related activities to somehow include these topics in impact evaluation considerations. However, we highlight that the extension proposals presented in this paper are just example ideas about how the current criteria can be extended based on the individual needs and focuses of the funding calls. It is up to the funding bodies and impact evaluators to decide how the extensions could serve the goal of the impact evaluation in the best possible manner, according to the case of each individual funding call.

As a second main topic in this paper, we presented an example of extending the newly introduced IIC model. As the IIC model has a practical two-dimensional structure for impact considerations in the inclusion-immediacy domain, it can also be utilized for considerations that focus on practical impacts related to commercialization. In our EIIC approach, we consider inclusivity on three levels: universal, stakeholder, and user. Especially the stakeholder and user levels are important from the practical commercialization point of view, since they measure what kinds of real benefits the research provides to direct project stakeholders, and what the benefits are for end-users of the innovations developed.

There is no single evaluation model that would fit all kinds of research. For this reason, we find it important to emphasize that the existing models can be modified, and that the models presented in this paper could work as examples of evaluation models for research with potential for commercialization in the short-term. The models for evaluating research impact tend to steer the planning of research projects, and thus effect the researchers' mindsets regarding their research activities. In this manner, new evaluation models emphasizing commercialization viewpoints may encourage researchers to consider practical viewpoints involving their research from business perspectives. This activity can foster an innovation mindset among university researchers, while facilitating interactions between academia and industry.

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Developing Social Impact Evaluation Methods for Research: viewpoints on commercialization and sustainability *Leena Kunttu, Helka Kalliomäki, Sorin Dan, Jari Kuusisto*

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Barriers to Value Specification when Carrying out Digitalization Projects

Sten Grahn, Anna Granlund, Erik Lindhult

"Tell me how you will measure me, and I will tell you how I will behave."

Eliyahu Goldratt
The Haystack Syndrome, North River Press, 1991
Author, Management Guru

If digitalization projects aim to effectively create value for a company, one precondition is having a shared view among company staff and project members of what the "desirable" value is. However, it has been shown that few companies fully understand the value that digitalization projects can create for them, while many companies still launch digitalization projects without this understanding. This contributes to the current "alarmingly" low success rate for digitalization projects. Development of effective methods to specify the desired values of digitalization projects is thus important. One step in developing improved specification methods is to ask what the possible barriers are to improving current value specification practices. The purpose of the current study is to address this. We analyzed several digitalization projects regarding how specifications of desired project value were carried out, finding that very limited resources are spent on specifying desired values in digitalization projects, and that this limits project success. Likewise, there are several barriers to increasing resources for specifying desired values. Our findings contribute to understanding the development of value specification methods that aim to overcome these barriers and thus could help improve the success rate of digitalization projects.

Introduction

The growth of competition, environmental challenges, and market changes make it ever more important for companies nowadays to ensure that they utilize resources as efficiently and effectively as possible. Rapid technological development also increases the technological opportunities to streamline businesses and take fuller advantage of existing opportunities to create more value, reduce resource consumption, and increase competitiveness. The World Economic Forum's "Digital Transformation Initiative" (WEF, 2021) states, for example, that: "Digitalization has immense potential: we estimate it could deliver around $100 trillion in value to business and society over the next decade". Carrying out effective digitalization projects has thus become an ever more important industrial and economic objective.

It has been shown, however, that few companies understand the value that digitalization can create for them (Gottlieb & Willmott, 2014), and that many companies still launch digitalization projects without this understanding (Gutschem, 2014). As organizations can gain more value from projects when the desired value is unambiguously specified in the early front-end planning stage (Terlizzi et al., 2017), likewise the absence of adequate value specification contributes to the current "alarmingly" low success rate for digitalization projects, according to Ismail (2018). One motivation for this study was to contribute to methods that can increase the success rate of digitalization projects. The overarching purpose was also to contribute to the "servitization" field by taking a value recipient perspective, given that servitization literature mainly takes a supplier perspective. The two servitization literature reviews (Carlborg et al., 2014; Raddats et al., 2019) for example, only briefly mention the recipient perspective.

Nevertheless, the ability to specify and communicate desired value as a means to generating desirable project outcomes depends on a company being able to identify

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values that are commonly desired and incentivizing for project actors (Dass, 2014). Rapid technological and market developments lead us to assume that the quest for finding a commonly shared view of what a desired long-term outcome is, as well as a commonly shared view of what is resource-efficient, will become an increasing challenge. These developments may make it possible, as well as necessary, to carry out digitalization projects that could render significant parts of the project's own members, along with other company staff, redundant (Rifkin, 1995, 2014; Brynjolfsson & McAfee, 2014), or lead to organizational changes that require new and demanding skills for the staff.

It can hence be challenging to find and use methods that specify the values desired in a way that incentivize all project members within companies, that support coordination of project resources when automation and other digitalization projects are carried out. but important to develop, as suggested by a comprehensive review on project front-end literature (Williams et al., 2019). This can be particularly important for small and medium sized enterprises (SMEs) as they report that the potential benefits of digitalization mainly have been framed towards larger firms (Müller et al., 2018).

Earlier, we studied how current value specification practice currently copes with potential disagreements regarding what counts as "desirable" long-term value from digitalization projects (Grahn et al., 2020). We found that potential disagreements generally were avoided by not specifying desired value at all, or with such low precision that there was nothing to disagree about. In that study, we also briefly mentioned other identified barriers. The present study expands on that previous study, intending to answer the question of what barriers exist to improving current value specification practices. Having a clear picture of existing barriers can guide companies to overcome these barriers, and possibly be a tool to increase the current success rate of digitalization projects.

The article is organized as follows: The first section describes how literature findings were used to shape the research approach. After describing our interview and workshop method, our empirical findings are presented. Finally, the empirical findings are analyzed, the identified categories of barriers are laid out in a table, and possible managerial implications of our research are outlined.

Using Insights from Literature to Shape the Research Objective

Projects can be viewed as a means to create potential value (Morris, 2009). If this potential value or benefit from a project is clarified before the project starts, the fundamental motivation behind the project decision also is clear (Project Management Institute, 2016). This activity of defining potential benefits, however often is given inadequate attention, (Breese et al., 2015; Badewi, 2016) incurring additional time and cost, as well as performance issues at later phases (Edkins & Smith, 2012).

Digitalization projects have the potential to generate several different benefits for a company, for example, by creating new or increasing the existing customers' values, customers may be willing to pay more, or companies may be able to reduce the need for the resources, and costs required for value creation. In this study "value" was, hence, viewed as a vector containing several value *"terms"* such as *production capacity, product usefulness, lead-time, useful information, etc*. Identified resource requirements which create this Value (V) (i.e. resources to install, operate and maintain digital installations) were also viewed as a vector of several Resource *"terms" (R)* such as *R (hours, machinery, maintenance/upgrade resources, etc)*. This study, then, observes how companies have treated their desired V creation and desired R reduction, and how different terms were weighted depending on the company's project specifications,

Stahel (2010) introduces the *time factor* concept, stressing the importance of recognizing that "performance" should be specified over a chosen time frame, that is, how created V and reduced R consumption should develop over a relevant time-frame. It has also been said that "The ability to learn faster than your competitors may be the only sustainable competitive advantage" (de Gues, 1988). An important outcome for any digitalization measure, thus, should be the achieving of as large an increase as possible for the fraction: *(Created Value) / (Resource consumption required for Value creation) (V/R) over time*. This indicates that industrial projects should secure both *optimizability* of tools, machinery, and production systems, providing secure *preconditions* for optimization, as well as contribute to full *utilization* of this optimizability. It was, therefore, relevant to observe how desired V and desired reduction of R were specified,

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in particular useful measurements of actual V and R, in order to be able to increase V/R over time. (From this point on, "value" means *"V/R over time"*.)

In summary, it was assumed that the ability to generate successful long-term value from digitalization projects is dependent on three main preconditions which specify how:

- Different value and resource terms should be prioritized and weighted.
- Desired increase of value *over time*, is to be created.
- Created value from the projects should be measured.

As the process for specifying the desired value of industrial digitalization projects was studied, it was relevant to reflect on possible barriers within the three aforementioned areas during this procedure.

It was also important to consider the already identified barriers for companies attempting to "servitize" their offers and shift focus from delivering products to creating customer value. Servitization studies that have taken this provider perspective have identified several barriers to this shift, for example, many customers are unaccustomed to the notion of paying for performance or function rather than the familiar concept of paying for products (Rexfelt & Ornäs, 2009), or, on placing a value on having a need met, as opposed to placing a value on owning products (Baines et al., 2007). Customers may also see strategic barriers and may not want to engage in deeper collaboration with the provider, due to fears of valuable company information being shared with entities outside the firm (Matthyssens & Vandenbempt, 2010). Other authors studying such barriers from the provider perspective mention issues related to lack of competency and skill (Lerch & Gotsch, 2015) or inadequate economic and management support (Ormazabal et al., 2016). When clustering the identified value specification barriers, it was assumed that the various provider barriers could be mirrored as recipient barriers. that is, as barriers for technology receivers wanting to "servitize" their digitalization project procurement process and shift focus from buying technology to creating value. This research, thus, categorized the thematic clusters as follows: Cultural barriers (Cu), Organizational barriers (Or), Competence barriers (Co), Support barriers (Su), and Other barriers (Ot). The data in each cluster was further submerged into suggested categories of barriers for each thematic cluster.

It is within such a context that this research asked the question: *What barriers should be considered in seeking to improve current value specification practices?*

Research Method

In order to identify barriers to value specification, the researchers interviewed companies regarding current specification practices and also held in-depth workshops with an international process industry company regarding the potential for enhancing digitalization project results by improving the value specification process. From the collected interview and workshop data, a list of different barrier categories was derived and further grouped into theory-driven thematic clusters.

As SMEs play an important part in the network of suppliers to larger enterprises, decreasing the gap in Industry 4.0 implementation between different enterprise categories is important (Sommer, 2015). With the emerging significance of ecosystems due to Industry 4.0 (Adner, 2017), building empirical knowledge on the SME's current practices will serve both to elucidate managerial implications and guide future research. The interviews and case studies were, thus, focused on SMEs and companies with limited digitalization experience. The subject of *desired value* is hard to grasp, and so, in order to identify relevant questions and get an in-depth understanding of how companies specify desired value, a data-gathering process in several steps with increasing refinements was employed. Value specification experiences from 21 companies were gathered and analyzed, so as to provide sufficient data which can then be generalized across various contexts (Leonard-Barton, 1995).

Experiences from an industrial consultancy firm

The research project was initiated by a study on the experiences of consultants from an industrial consultancy company related to 30 different industrial automation projects between 2004 and 2014. The

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following open-ended question, “How are your customers generally specifying desired value from digitalization projects?” was asked to three consultants within that company. Using the answers from the ensuing discussions, interview questions were generated for the systematic interviews with the companies in this study.

Responses to mailed questions and subsequent interviews with SMEs and two digital tools suppliers

A set of six questions, all centering around value specification in digitalization investments, was mailed to the engineers responsible for production development at 17 Swedish industrial SMEs. In collecting data, both responses to the questions and findings from subsequent semi-structured interviews (Walsham 1995) were used. The questions answered were:

1. How is the desired value from digitalization projects specified?
2. How is economic value ensured from digitalization projects?
3. How is actually created value measured?
4. How is desired value over time specified?
5. What business model is used to purchase digitalization projects?

The digitalization recipient interviews above were complemented with interviews with two digital tools suppliers. The suppliers were asked to express their view on how their customers generally specify the desired value from digitalization projects, so as to provide an indication of whether recipients and suppliers are in agreement on how recipients specify the desired value.

In-depth analysis of value specification practices at an international process industry company

Finally, a series of six workshops was held with participants from one midsized international process industry company, with the purpose of identifying how outcomes of future digitalization projects could be improved, specifically, by better developing the value specification process. These workshops involved the production manager, the manager for the IT-department, project leaders for individual digitalization projects, and affiliated automation consultants. The following five topics were covered throughout the six workshops, namely, “why is our current project success rate limited?”, “how do we specify the desired project ‘success’?”, “how are our organizational and project models supporting the specification of desired ‘success’?”, and “how could our project design be improved?”. Since the digitalization project maturity of the company could not be viewed as leading-edge, their potential benefit from such discussions served as a reason for the company’s interest in participating in the workshops.

Data analysis

To structure the analysis, the collected interview data was grouped into theory-driven thematic clusters.

Regarding the international midsized process industry, the more detailed information from their workshops was used to analyze potential organizational barriers as well as how actual outcomes from earlier projects had differed from specified desired outcomes. By getting an indication of how insufficient specified desired value could be, and how this attributed to unsatisfying actual outcomes, it could be assumed as part of the reason for the suboptimal results for digitalization projects within the group of SMEs. Using this information, this research was able to indicate whether any particular barrier was especially important for project outcomes.

Empirical Findings

This section summarizes answers to the aforementioned questions, interview findings, and workshop investigations, illuminating the current value specification practice in digitalization projects, as a way to identify possible barriers.

Long-term experience in value specification from industrial consultants

Responses to our open-ended questions indicated a generally limited interest in precise specification of desired value from recipients of digitalization projects. Comments from one consultant were as follows, *“During all my years, I have never come across companies that really consider the questions of desired value. There generally is instead a focus on a relatively few project targets, mostly technology specifications. ‘Lowered production cost’ is often the desired ‘value’… Limited interest in detailed value specification is also easy to understand as overhearing ‘locker room talk’ often reveals a wide-spread concern about outcomes from digitalization projects, regarding possible job losses and*

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demanding new work requirements”. Based on these experiences, a set of questions to the SMEs was produced leaving out the question, “How are possible disagreements avoided regarding what is ‘desired value’?” as it was considered a sensitive topic.

Responses to mailed questions and subsequent interviews with SMEs, and two suppliers of digital tools

The answers indicate that most SMEs are unaccustomed to the very concept of “specifying the desired value” from digitalization projects. Further, the responses revealed several significant categories of barriers as shown in Table 1 below. Standardized routines for equipment choice, installation, operation, and upgrading were generally followed to secure low project costs, which was assumed to also create long-term value for the company. This was not the case though, as the project routines to secure low project cost, generally generated high long-term company costs, as numerous, costly, activities were required after the projects had been ‘finished’, to make things function properly. Answers from suppliers supported the view that recipients generally display disinterest for specifying the desired value, or measuring the created value, as is also shown in Table 1.

In-depth analysis of value specification practices at an international process industry

The workshops identified that several project specifications were in place before digitalization projects started, such as the desired project start date, project finish date, project cost, technical specifications such as the theoretical capacity of specific machinery, ability to make measurements with a certain precision, and ability to control certain process settings. Basic specifications of what the final production machinery should do were also in place, such as “palletizing”, “packaging”, and “labeling”. “Verified usefulness” from different stages of the project, such as explicitly *useful* packaging, labeling, measurements, or control, were only, however, specified to a limited extent, or not at all. This research, thus, found that the absence of specified *useful* communication was particularly important for the [in]ability to create increased value over time:

- Resource requirements for creating useful solutions to access process data and control signal transmissions were not specified at all. Resource requirements for these purposes, were highlighted as significant by some workshop participants who viewed these solutions as necessary for the creation of information that would be helpful for optimization. Other decisions, however, require several steps to access, such as solutions for filtering, format choice, data location solutions, and data analysis, as well as admission to data through company firewalls under IT-security policies at the company.

- Most workshop participants perceived limited problems with the above, as they had a relatively static view of digital installations, viewing them comparably to physical infrastructures such as buildings. This meant that they had a limited understanding of the benefits of being able to automatically and continuously control a system, the differences between non-optimized and optimized systems, and the improvement potential from optimization efforts. Optimization efforts were even mentioned as undesirable, as it was deemed too much of a risk that an improperly designed optimization procedure may cause costly process disturbances, or even completely stop the production process. Other workshop participants, however, highlighted that past successful optimization endeavors had generated improvements of *V/R* beyond 30% for several processes, and that “optimizability” should be a desirable value.

The absence of useful information and communication harmed the ability for resource-effective production, as any ”useful” production capacity had to be secured after the projects were finished, requiring significant resources. Possibilities to rapidly, robustly, and automatically control process settings to increase value over time – “optimizability”– were nearly non-existent, as this was dependent on things like useful information and control.

Another important factor contributing to these results was that project participants generally prioritized requirements to carry out the work and deliver the [limited] technical specifications described in the project order within time and budget constraints, instead of prioritizing non-specified production value.

Individual job descriptions, project manuals, and project instructions described what individuals should work with, *how* all project steps, from project idea to project handover, should be handled, and *who* should be

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responsible, Nowhere, however, did these mention the concept that desired value from work or project steps should be specified and validated.

Resources required to secure higher productivity of the installations after the automation projects had been finished, that is, the optimization efforts, were not considered *project costs* but rather *production costs*. Some workshop participants also indicated that the significant after *project costs*, for instance, tuning of the machinery to make it produce anything, could actually be viewed as a positive outcome for those project participants who would be beneficiaries of these resources.

Another finding showed how discussions about technology specifications, such as “power” or “speed” of machines, was generally regarded as significantly more interesting than discussions about how specifying the *desired value* from machine utilization could guide those choices of power and speed. The reasons for this were not clearly spelled out, but through the comments that emerged, one could gather that value was not regarded to be as “fun” a topic as power. Further, there were even concerns that thorough value specification could contribute to insights that might indicate certain “fun” and “good to have” machines as unnecessary.

The study of completed projects also showed that projects only involving limited amounts of programming (mainly physical structures) typically generated more satisfying finished products compared to installations involving significant amounts of programming. This result was indicated as being on account of the static nature of physical constructions. Here it was easy for all to see and measure if the final result created high value.

Analysis

From the empirical findings, a total of 16 categories of barriers could be identified over the five thematic clusters. For the clusters “Support” and “Other” only one category was found. The identified categories of barriers were:

- *Support barrier (Su):* No explicit support for value specification activity from company leadership.

- *Organizational barrier (Or) categories:* Limited resource allocation for value specification (Ora), Organizational structure making it too challenging to identify total company value over time, rendering value specification irrelevant (Orb), Some organizational units benefiting from low long-term resource efficiency, reducing incentives to specify a desired resource reduction (Orc), Strategic choices to not use business models where providers are remunerated for created value, reducing incentives to specify the desired value (Ord), Project models that do not require specifying desired value or evaluating created value (Ore), Project models rewarding low project cost instead of high value creation (Orf).

- *Competence barrier (Co) categories:* Limited competence to specify the desired value (Coa), to measure created value (Cob), to take secure advantage of information useful for optimizing operations (Coc) or, to write contracts where providers are remunerated for created value (Cod).

- *Cultural barrier (Cu) categories:* Habit (Cua), Belief that fulfilled technology specifications will create value (Cub), Belief that focus on one or a few values, such as “improved ergonomics” also will create other values efficiently (Cuc), Viewing value specification as an undesirable activity (Cud).

- *Other barriers (Ot):* Impossible to know in any detail what value an investment may create over time, making value specification irrelevant.

Representative answers for each cluster and category are found in table 1 (PA indicates a digitalization Provider Answer, WS indicates results from the workshops).

By not specifying the desired value from digitalization projects, one also erects a unfortunate barrier from other vital specifications that are important for optimizing systems and resources effectively, so as to create an increase in value over time:

- Without a clearly defined desired value, specifying how to measure created value becomes less relevant. “Useful" measurements and information (such as that for effective system control) were never mentioned as desired value.

Table 1. Cluster, category, and *representative answer* or result from the workshops

Cluster	Category	***Representative answer*, or result from the workshops (WS)**
Su		No indication that leadership requires the desired project value to be specified
Or	Ora	*"We have very limited resources to specify…how created value should be measured or to what degree the IT-department's technology specifications will actually generate value for the Production department."*
	Ora	(PA) "*Desired values are 'faster processes', 'fewer errors', that could be relatively easy to specify and measure if customers were more interested in doing that."*
	Orb	(WS) The organizational structure makes it too challenging to identify total company value over time, making value specification irrelevant.
	Orc	*"We are [also] aware that these 'savings' in specification resources generate substantial resource consumption later on, to fix everything that does not work after a digitalization project has been 'finished.'"*
	Orc	(WS) Limited incentives for organizational units to maximize total company value over time
	Ord	*"Payments to digital tool providers are not connected to created value in our company… Value focused contracts doesn't suit our current business model…"*
	Ore	(WS) Project models only focused on securing technology specifications, not on creating value
	Orf	(WS) Strong incentives to minimize short term project/technology costs
Co	Co(a-d)	(WS) Limited knowledge of how to specify, to measure, evaluate and pay for created value
	Cob	*We have no method to further measure the value of IT projects except assuming that automating the CAD process will lead to value."*
	Coc	(WS) Percieved IT-security and Production risk: Optimization too challenging: 'Optimizability' irrelevant value
Cu	Cua	*"We do not have any method for evaluating the value of our projects. Instead, we look at the overall figures we have in the business. For example, delivery security, number of completed orders or 'the last line in the annual accounts.'"*
	Cub	*"We evaluate technical specifications…rather than the value of the functions."*
	Cuc	*"The IT projects we have, have currently focused on reducing lead-time by reducing the need for manual working hours. The value for the company has been implicitly assumed concerning the nature of the project."If there are ergonomic improvements, it is always worth it."*
	Cuc	(PA)*"I wish they [customers] focused more on value, but the focus is almost only on estimated cost reduction."*
	Cud	(WS) Value specification is viewed as an undesirable/boring activity
Ot		*"The total impact of investments over time is difficult or impossible to predict in any detail"*
		(WS) "Impossible" to know the future value from digitalization in detail, why specify?

Barriers to Value Specification when Carrying out Digitalization Projects

Sten Grahn, Anna Granlund, Erik Lindhult

- Without useful information, specifying the value "optimizability", that is, the possibilities for effective, continuous system optimization (system control to increase V/R over time) is not relevant, as this is dependent on useful measurements of *V, R,* and *process settings.*

Competence and organization are also important barriers to specifying "optimizability" as this requires an understanding of the concept, as well as continuous access to useful information and control signals. Securing this may prove a challenge for company IT-security and organizational policies in order to determine who can do it, when, and how. By some people's indications, this would present many hard challenges (Coc) to overcome and would present a path not worth pursuing.

In addition to IT-security risks, production risks were also indicated as a competence barrier to "optimizability" specification. Concerns that safe constraints for process settings would be challenging to establish indicated that identification and fixing of process settings that "work" is more interesting than optimization (Coc).

We, thus, interpret our findings as demonstrating how the lack of leadership and organizational support is a crucial barrier to value specification. Within the thematic clusters identified from the literature, we identified several different types of barriers, such as various organizational barriers that may work in concert to bar value specification efforts. Our findings also indicate that this may have a significant impact on specification competence barriers, as well as on cultural barriers. The lack of precisely specified desired value makes the specification of value measurements, value control, and optimizability irrelevant objectives, while perceived risks and challenges connected to optimization efforts further strengthen the "irrelevance" barrier.

The findings from the workshops showed that imprecise value specification led to various unsatisfying project outcomes. For each of the projects studied in the workshops, the consequences implied that significant resources were required to facilitate effective utilization of the digital installations. To adjust production when, for example, products changed, and to effectively optimize the production was inconvenient at best, if optimization was even possible after the digitalization projects had been "finished". "Inflexible solutions" also served as a reason for many SMEs participating in the interview study. As the SMEs and the process industry responded similarly to our questions, we found it reasonable to assume that the SMEs imprecise or absent value specifications contributed to their "inflexible solutions" outcomes, as it did for the process industry.

Despite the identified or assumed (as in the case for the interviewed SMEs) unsatisfactory project outcomes which resulted from unprecise value specifications, this practice was generally uncontroversial, and actually seen as beneficial for several reasons. For example, it avoids a potentially resource-demanding, "wasteful" challenging, or boring activity. It also makes it easier to keep precise information of how equipment and projects will increase value classified for digital tool providers.

In summary, we discovered several multi-faceted barriers companies face when looking at increasing resources for specifying desired value from digitalization projects. The findings also indicate that challenges for digital providers may be rooted in the difficulty customers face in trying to identity a specific value for which to pay; attempting to servitize their offers and find customers willing to shift the business model from paying for advanced digital technology to paying for created customer value often proves quite difficult.

Conclusions and Suggestions for Future Research

Our findings indicate that improving value specification could be a significant challenge. The managerial implications for SMEs propose that methods to reduce the "alarming" failure rate of digitalization projects must address and overcome several different barriers, including the identification of what "failure" and "success" mean for whom in the organization, and a reflection on the difference between the *short-term resource-efficient* following of organizational and project models and efficient securing of technical specifications, and the *long-term resource-effective* ability to create company value (Sink & Tuttle, 1989).

Another implication of our research findings is that digitalization providers that attempt to "servitize" their offers and focus on creating customer value, rather than sell advanced technology, may benefit from attempting to identify the fairly limited number of customers who have a clear picture of what value they want to create

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with their digitalization efforts.

Since the front-end project stage is currently not clearly understood within academia (Williams et al., 2019), this study contributes to increased understanding and insight on the topic. It also advances servitization and value research by taking the digitalization value recipient perspective, which few servitization studies cover at present. Further, it suggests an indicative structure of different barriers to value specification, and, thus, barriers to servitization efforts, and proposing that methods to overcome those barriers should be developed. It also recommends that the development of such methods must consider several questions which ought to be investigated in future studies, for example, what efforts may be most effective when attempting to dismantle existing value specification barriers.

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