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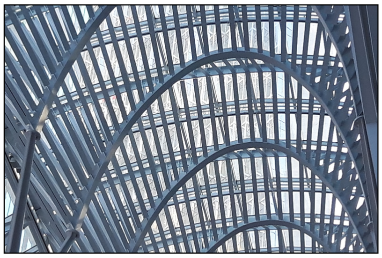
Allen Lambert Galleria, Toronto. Photo: C. McPhee (CC-BY)

Insights

Welcome to the June issue of the *Technology Innovation Management Review*. We welcome 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.

We welcome input from readers into upcoming themes. Please visit timreview.ca to suggest themes and nominate authors and guest editors.

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About TIM

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

Chris McPhee, Editor-in-Chief

Welcome to the June 2017 issue of the *Technology Innovation Management Review*. The authors in this issue share insights on creativity training, internal communication management, competitive intelligence, university–industry collaboration, and cybersecurity in the Internet of Things.

The four articles in this issue were based on papers presented at the ISPIM Forum in Toronto, Canada, in March 2017. ISPIM (ispim-innovation.com) – the International Society for Professional Innovation Management – is a network of researchers, industrialists, consultants, and public bodies who share an interest in innovation management. Next year's ISPIM Forum will be held in Boston, USA, from March 25–28, 2018. Submissions from academic, research, consulting, industry, intermediary, and policy organizations are encouraged, and the submission deadline is November 24, 2017:
ispim-innovation-forum.com/submissions

In the first article, **Dagny Valgeirsdottir** and **Balder Onarheim** from the Department of Management Engineering at the Technical University of Denmark introduce the Creative Awareness Training program. Based on their Know–Recognize–React model, this creativity training program is designed to be both theoretically sound and relevant to practitioners, helping them to not only be more creative but also to raise their level of creative awareness, both of which are crucial skills in innovation.

The second article is by **Tuomo Eskelinen** and **Ulla Santti** from the Savonia University of Applied Sciences in Finland and **Mervi Rajahonka** and **Kaija Villman** from the South-Eastern Finland University of Applied Sciences XAMK. These authors seek to help SMEs to overcome the challenges of internal information management through service design tools and processes, such as participative business model techniques. Their service design approach based on CIMO logic (context, intervention, mechanism, and output) showed that a participative business model technique and process can identify problems and challenges in internal communication management, as well as in the prioritization of actions.

Then, **Andrew Droll** and **Shahzad Khan** from Gnowit and **Ehsanullah Ekhlas** and **Stoyan Tanev** from the University of Southern Denmark use the Gnowit Cognitive Insight Engine to evaluate the growth and competitive potential of new technology startups and existing firms in the newly emerging precision medicine sector. The Gnowit engine is a web search and analytics tool that uses techniques founded in web content scraping, natural language processing, and machine learning to assess online documents and media discussions. The preliminary results suggest that this competitive intelligence tool can provide entrepreneurs, investors, managers, and entrepreneurship scholars with insights about emerging sectors.

In the last article, **Koichi Nakagawa**, **Kosuke Kato**, **Terumasa Matsuyuki**, and **Toshihiko Matsuhashi** from Osaka University in Japan and **Megumi Takata** from Kyushu University in Fukuoka, Japan, evaluate the Global Technology Entrepreneurship and Commercialization (G-TEC) program at Osaka University. This university–industry collaborative education program brings together participants from universities and industry in a temporary and extraordinary setting, which acts as a "trading zone" for the exchange of knowledge about the theory and practice of entrepreneurship. Through their analyses, the authors develop a set of propositions to encourage further study and application of this form of university–industry collaboration for entrepreneurship education.

This issue also includes a summary of a recent TIM Lecture entitled "Building Trust in an IoT-Enabled World". **Jeremy Watson** (President of the IET), **John Marshall** and **David Mann** (inBay Technologies), **Mike Young** (Bastille), and **Peter Smetny** (Fortinet) offer their perspectives on cybersecurity challenges in the Internet of Things (IoT).

In July, we celebrate the 10th anniversary of the TIM Review and will take the opportunity to thank all of our readers and contributors and to reflect on the topics and author perspectives that have been covered in a decade of monthly issues of this journal.

Editorial: Insights

Chris McPhee

For future issues, we are accepting general submissions of articles on technology entrepreneurship, innovation management, and other topics relevant to launching and growing technology companies and solving practical problems in emerging domains. Please contact us (timreview.ca/contact) with potential article topics and submissions.

Chris McPhee
Editor-in-Chief

About the Editor

Chris McPhee is Editor-in-Chief of the *Technology Innovation Management Review*. He holds an MASc degree in Technology Innovation Management from Carleton University in Ottawa, Canada, and BScH and MSc degrees in Biology from Queen's University in Kingston, Canada. Chris has nearly 20 years of management, design, and content-development experience in Canada and Scotland, primarily in the science, health, and education sectors. As an advisor and editor, he helps entrepreneurs, executives, and researchers develop and express their ideas.

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Keywords: creativity, training, internal communication management, service design, competitive intelligence, university–industry collaboration, entrepreneurship, cybersecurity, Internet of Things

Realistic Creativity Training for Innovation Practitioners: The Know–Recognize–React Model

Dagny Valgeirsdottir and Balder Onarheim

"Know where to find the information and how to use it. That is the key to success."

Albert Einstein (1879–1955)
Theoretical physicist and Nobel laureate (1921)

Creativity is increasingly being recognized as important raw material for innovation, which highlights the importance of identifying ways to increase the creativity of practitioners. In this article, we describe our efforts to design a creativity training program specifically for innovation practitioners. Our aim was to develop a program that would be both theoretically sound (i.e., based on a rigorous scientific foundation) and relevant for practitioners (i.e., applicable to real-world contexts). Our transdisciplinary study employed co-creation as a method to ensure that three layers of focus would be taken into consideration: metacognitive knowledge, metacognitive monitoring, and metacognitive control. The result is a program called Creative Awareness Training, which is based on the new Know–Recognize–React model.

Introduction

It is widely accepted in academic circles that creative thinking is an important element in innovation (e.g., Amabile, 1996; Christiaans, 1992; Dorst & Cross, 2001). Creativity is moreover believed to be the necessary precondition for innovation; one may argue that without the presence of a creative act, idea, or output, no innovation will happen. Indeed, Amabile and colleagues (1996) state that "All innovation begins with creative ideas". This is the root of our interest in enhancing creativity, which we see as the raw material of innovation: the individual creativity of innovators.

Creativity is a basic human skill, which can indeed be transformed gradually through long-term education, however, numerous studies have demonstrated that this skill can also be improved through shorter interventions such as dedicated training programs (see e.g., Scott et al., 2004). Many different approaches to creativity training have been established, although most current creativity training programs are directed at enhancing individual creativity skills on a cognitive level (Scott et al., 2004). Despite a multitude of training approaches in the current landscape, there seems to be a lack of rigorously developed and tested creativity training programs (Valgeirsdottir & Onarheim, in press) designed specifically for practitioners in the fuzzy front end of innovation, as defined by Koen and colleagues (2002), hereafter termed *innovators*.

To address this gap, we undertook a series of studies, the fourth of which is described in the present article (Figure 1). We first set out to investigate how creativity skills influence the creative process of innovators with the purpose of determining what is important to them when using creative thinking abilities. Through an initial research effort – Study A (Valgeirsdottir et al., 2016) – we found that, when individuals showed awareness of the creative process flow and the underlying cognitive processes accompanying it, and used this awareness to facilitate their own and their team members processes, it appeared to benefit the collective creative process. Following Study A and a related literature review (Study B: Valgeirsdottir & Onarheim, in press), we wanted to elaborate on and investigate this finding through observational research (Study C: Valgeirsdottir & Onarheim 2016). Resulting from that work, we developed a definition of a metacognitive creativity skill we termed "creative awareness", which will be described in more detail

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below. The current study builds on these three previous research efforts by developing a training program that would enable creative awareness of creativity-related processes. By adapting methods from transdisciplinary strategizing (e.g., Rasmussen et al., 2010) and co-creation (Sanders & Stappers, 2008), we developed a creativity training program specifically designed for innovators. The overall research process can be seen in Figure 1 below, with the current study and its five interventions (IVs) being delimited to the "co-creation" section of the figure.

The overall research question we defined for our study was: *Which creativity concepts and cognitive processes are important to emphasize in training to enable creative awareness?* This question was addressed at three different levels of stakeholders (see Figure 1) in a creativity training context:

1. Relevant: involving representatives of *innovators* to ensure a relevant training program
2. Theoretically sound: involving creativity *academics* to establish a program that is theoretically sound
3. Realistic: involving *company representatives* responsible for employee development (i.e., HR managers) to provide the perspective of what is realistic in a real-world context

The preliminary program design, resulting from the first three interventions, was then introduced to educational researchers for validation through two additional interventions to ensure a robust design (Rasmussen et al., 2010). The purpose of this article is to describe our transdisciplinary study and the co-creation process we designed to investigate these aspects, as well as the resulting conceptualization of our creativity training program: "Creative Awareness Training".

The article is structured as follows. First, we provide a theoretical background, framing the key concepts in a broader perspective. Next, we describe the methodolo-

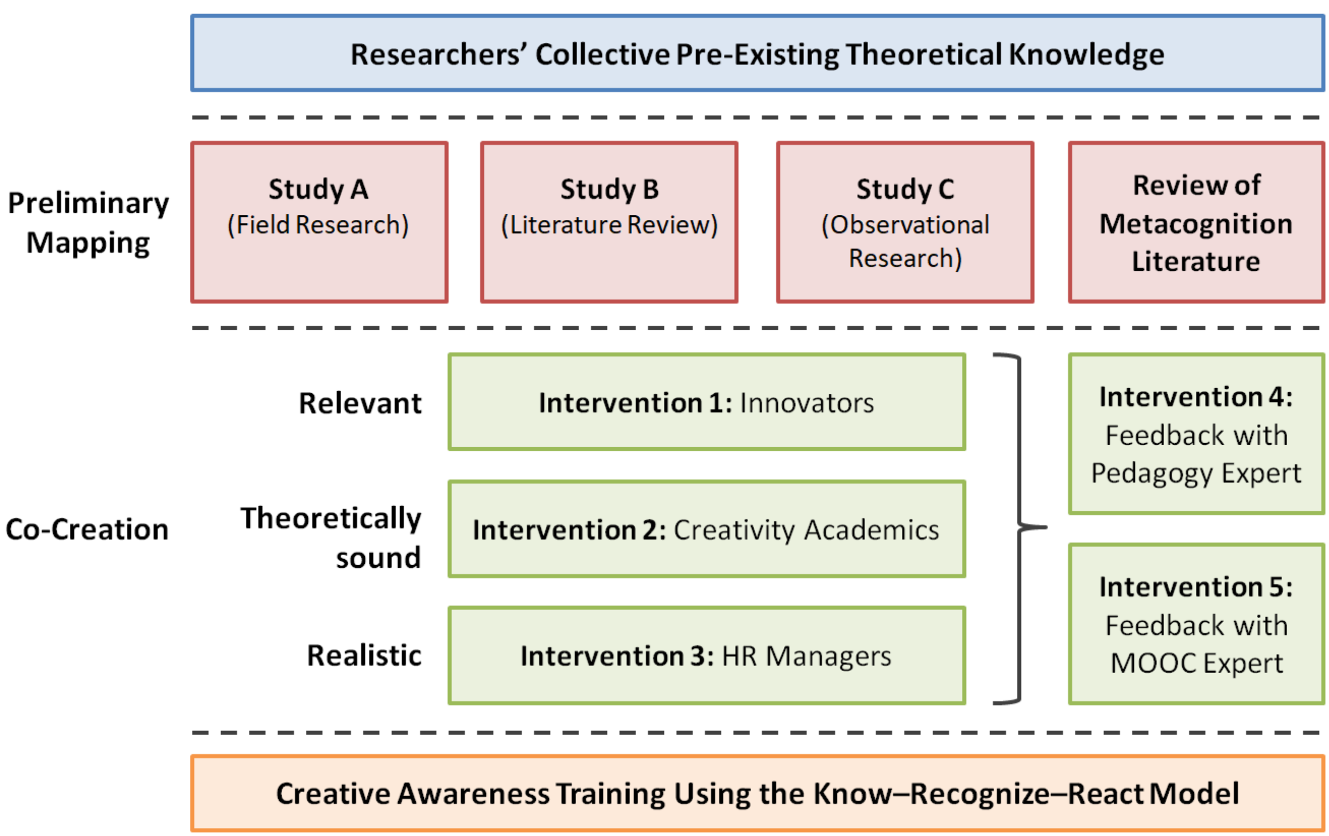

Figure 1. Overall research process leading to the development of training program. The "co-creation" portion of the process delimits the current study.

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gical approach and present the findings from the transdisciplinary process. Finally, we discuss the findings, outline the conclusions, and highlight the practical implications and contribution to the fields of creativity and innovation management.

Theoretical Background

Theoretical approaches towards creativity may be considered in terms of which form of creativity they emphasize, taking departure from the four Ps of creativity (Rhodes, 1961) which list the creative *person, process, product,* and *press* (more recently, *persuasion* [Simonton, 1990] and *potential* [Runco, 2003] have been added). In our studies of creativity training, the main focus is on two of the original Ps, namely the creative *person* and the creative p*rocess.*

Further forming the theoretical background of our research are two out of the nine major theories of creativity, as categorized in *The Cambridge Handbook of Creativity* (Kozbelt et al., 2010). Both categories our research aligns with belong to the psychological standpoint of creativity research (e.g., Guilford, 1950; Mednick, 1962). First, we shall mention the *psychometric* category that is formed in part by representative theories built on the work of Guilford (e.g., 1968) and Wallach and Kogan (e.g., 1965). Within this category, the major focus is on the creative person and the argument that creativity can be differentiated from other constructs such as IQ and can be measured reliably through psychometric tests (Kozbelt et al., 2010) such as the alternate uses test (Christensen et al., 1960; Guilford, 1968) and instances task (Wallach & Kogan, 1965). The focus of these tests is divergent thinking, which is the cognitive process of generating multiple ideas to a given task (Guilford, 1959). It is the cognitive process that is argued to be trainable and therefore emphasized in many creativity training programs as well as serving as the most common construct of measure (see e.g., Valgeirsdottir & Onarheim, in press). Divergent thinking is usually accompanied by another cognitive process, convergent thinking (Guilford, 1959), and as pointed out by Onarheim and Friis-Olivarius (2013), these two processes each relate directly to two key features of the standard definition of creativity (Stein, 1953; Runco & Jaeger, 2012): novel (divergent) and appropriate (convergent). The second category of our work falls under cognitive theories of creativity, which relate to Guilford's "Traits of Creativity" (1959) and the "Associative Basis of the Creative Process" (Mednick, 1962). The cognitive category primarily focuses on the creative person and process, and the primary assertion is that ideational processes are fundamental to the creative person and their subsequent accomplishments in a creative process (Kozbelt et al., 2010). Metacognitive processes are furthermore one of the key concepts within this category, which we will examine in the next section.

Metacognition and creative awareness

Creative awareness is, as previously stated, a skill that is closely related to metacognition from psychology literature, which refers to "thinking about one's own thinking" (Dunlosky & Metcalfe, 2008; Flavell, 1979). Metacognition is a cognitive system that helps direct the way individuals solve their tasks through sub-consciously overviewing cognitive functions. There are three facets to metacognition: metacognitive knowledge, metacognitive monitoring, and metacognitive control (Dunlosky & Metcalfe, 2008). Metacognitive knowledge is knowledge about a given type of cognition (e.g., learning, memory, reasoning, and creativity). Metacognitive monitoring happens when one assesses the current state of cognitive activity (e.g., assessing whether they would be more successful in solving the task at hand using other cognitive strategies). Metacognitive control follows if the individual, as a result of their metacognitive monitoring subsequently regulates some parts of their cognitive activities. Metacognition is a broad concept, encompassing all types of cognitive activities, and we see metacognition as being an umbrella concept under which creative awareness fits. Creative awareness is limited to creativity-related acts, and not other distinct cognitive processes. It materializes when individuals are aware of the different stages of their creative process, as well as the underlying cognitive processes that could influence their creative abilities. This awareness is also beneficial for advancing the team process (Valgeirsdottir et al., 2016; Valgeirsdottir & Onarheim, 2016). We define creative awareness as follows:

> *"Creative awareness is a cognitive creativity ability that individuals in a team use to facilitate a creative process. This creative process can be either their own, their team's or when designing a process for other participants. The individual applies their knowledge of cognitive processes and creativity concepts, by being aware of the potential influence of said processes and concepts on the creative process."* (Valgeirsdottir & Onarheim, 2016)

Creative awareness is an ability that allows an individual to become conscious of the cognitive processes involved in a creative process, such as divergent and convergent thinking (Guilford, 1959), associational processes (Mednick, 1962), and the five key concepts of creativity (Onarheim & Friis-Olivarius, 2013), which in addition to "remote associations" include cognitive inhibition, priming, fixation, and incubation. This ability requires both knowledge of said processes and self-observation and regulation in line with metacognition in order to understand one's own and other's creative processes. The deployment of the creative awareness ability may thus enable the individual to enhance their creative potential. It also enables them to be more deliberate when getting involved in a creative process to avoid possible pitfalls and to generate required conditions through regulation and subsequent reactions to advance the creative process. Therefore, it seems relevant to teach participants about cognitive processes in creativity training and employ metacognitive methods to enable creative awareness.

Creativity training

Creativity training programs are not a new phenomenon; the first known program dates back to 1953 (Osborn). Several meta-analyses comparing results of individual studies on training efforts have been published (e.g., Rose & Lin, 1984; Scott et al., 2004; Ma, 2006), with the study by Scott, Leritz, and Mumford (2004) being the most prominent. Their review of 70 programs revealed that many different approaches have been deployed with the purpose of enhancing creativity, but the most important result of the meta-analysis was that creativity training does work (Scott et al., 2004). However, due to the lack of definitional clarity of "creativity training programs" we have proposed the following definition:

> *"A creativity training program is a pre-defined and structured program consisting of one or multiple sessions, with the main purpose of increasing the creativity of one or multiple participants."* (Valgeirsdottir & Onarheim, in press)

The review by Scott and colleagues (2004) provides an overview of previous training efforts and the different aspects of creativity they focused on (e.g., problem solving, associational mechanisms, and divergent thinking). Earlier, Bull and colleagues (1991) identified four common approaches to creativity training: cognitive, personality, motivational, and social interaction approaches. More recently, we reviewed the identified categories with a focus on the methods of delivery: traditional, computer-based, physical, and cognitive (Valgeirsdottir & Onarheim, in press).

Divergent thinking is the most common skill in focus in creativity training programs (Fasko, 2001), however, focus has also been put on problem-solving abilities. Problem solving is the foundation of many established creativity training programs such as the Creative Problem Solving program (Parnes & Noller, 1972). Scott and colleagues (2004) proposed an optimal format for the delivery of creativity training, which consists of four key aspects:

1. Training should be built on teaching about the cognitive theories of creativity

2. The theoretical teaching should be a substantial part of the overall length of the training, and it should be detailed in describing the cognitive and associative skills underlying creative effort.

3. After learning about the attributes underlying creative effort, the participants should put them to use while solving a real-world case in a co-operative learning environment.

4. The presentation of the case material should be complemented by diverse exercises and tools to provide participants with practice in using relevant strategies and heuristics while solving the real-world case.

Research Design

In this article, we will describe our transdisciplinary study. A transdisciplinary approach "includes interdisciplinary but goes a step further and transcends the margin of science" (Rasmussen et al., 2010) where non-scientific stakeholders are included in the production of knowledge (Lengwiler, 2006). Our study had the aims of investigating which creativity skills are important for raising creative awareness and developing a training program for innovators through using the method of co-creation (Sanders & Stappers, 2008). The reason for selecting a co-creation approach was to ensure that the program is relevant, theoretically sound, and realistic for a real-world context.

Co-creation process

In co-creation, there are two approaches that should be taken into consideration. First is the overarching co-creation process the researchers plan with a pre-defined purpose as well as preliminary mapping of pre-existing knowledge (Visser et al., 2005). In this case, the preliminary mapping (Figure 1) consisted of two years of prior research efforts, which included Studies A, B, and C

(Valgeirsdottir et al., 2016; Valgeirsdottir & Onarheim, in press; 2016). Second are interventions strategically placed at different intervals within the overarching process. The interventions are deployed with the aim of reaching the pre-defined purpose of the co-creation process utilizing pre-planned methods and carefully selected participants (Visser et al., 2005). Interventions can take the form of feedback sessions, expert interviews, and generative sessions where scientific or non-scientific participants are included in knowledge production and material analysis (Rasmussen et al., 2010). Data collection can be in the form of researcher notes and material generated by participants during sessions. In co-creation, researchers are facilitators and encourage participants to express themselves (Sanders & Stappers, 2008). The interventions deployed here were three generative sessions designed to explore the tacit and latent knowledge of the participants (Visser et al., 2005) through specific exercises and instructions. Further interventions were two feedback sessions with educational scientists who utilized their knowledge to validate pedagogical aspects of the training program to ensure optimization when we further concretized it.

Descriptive aspects of co-creation interventions

The optimal number of participants in generative sessions is between four and six (Visser et al., 2005). Intervention 1 included six participants whose knowledge would ensure a *relevant* program for innovators. The participants shared their knowledge on the topic, and facilitators probed into their tacit knowledge of what would be of most value to them to include in the training. The participants all had more than five years of professional experience working within the fuzzy front-end of innovation and their positions at the time are listed in Table 1. Their industries are listed as well, although they were not the focus in selecting the participants; the focus was more on the innovation process and the participants' experiences from the fuzzy front-end.

Table 1. Occupations and industries represented by participants in Intervention 1

Occupation	Industry
Senior R&D user research lead	Healthcare
Senior UX researcher	Digital industrial
Senior UX researcher	Automotive
Chief principal innovation manager, R&D	Medical equipment
Industrial designer and entrepreneur	Medical equipment
Innovation manager, FE innovation	Medical equipment

The output from Intervention 1 was used to design parts of Intervention 2. The purpose of doing so was to ensure that the elements included in the program design from Intervention 1 would be *theoretically sound*. Secondly, a theoretical perspective was gained through facilitated probing into their expert knowledge on the topic. Participants in Intervention 2 were four academic employees at three Danish universities. Each of them had expertise in creativity research and teaching responsibilities in creativity related courses, each with minimum seven years of academic experience.

The outputs from Interventions 1 and 2 were synthesized (as described below) and used to design parts of Intervention 3, which had the purpose of gaining insights from four practitioners with experience in human resource (HR) management (Table 2) in major Danish companies. This intervention was done to ensure a *realistic* program for real-world contexts in terms of both content and format of the training program, such as the length and time distribution.

The output from the first three interventions was, again, synthesized and presented to two academic scientists in Interventions 4 and 5, where an expert in pedagogy and education was consulted as well as an expert in massive online open courses (MOOCs). The purpose of the two last interventions was to present the experts with the first draft of the training program and obtain feedback regarding pedagogical aspects and program design. These sessions were validating in nature and contributed to the robustness of the final version of the training program.

Table 2. Occupations and industries represented by participants in Intervention 3

Occupation	Industry
HR development consultant	HR consultancy
HR business partner	Banking
HR development consultant	Banking
HR business partner	Engineering

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Data analysis

Below is a description of the process of analysis for the generative sessions (Interventions 1, 2, and 3). The feedback and validation sessions (Interventions 4 and 5) will be addressed in the section on Findings.

Data collected during generative sessions was in the form of researcher notes, video recordings, and other generated material such as notes written by participants, templates filled out, etc. The data was analyzed in the manner of analyzing case studies (Eisenhardt, 1989), where each session was treated as a case. The analysis was done systematically throughout the process where data from each intervention underwent four levels of analysis, or "filters", as shown in Figure 2, and described below:

- *Filter 1:* The analysis began during each session when participants filtered their own material, for example by summarizing and prioritizing outputs into Top 3 lists.
- *Filter 2:* At the conclusion of each session, the researchers went through generated material and chose which to collect from the session.
- *Filter 3:* In the days following each session, the researchers reviewed the data, synthesized it further, and organized the results in digital form.
- *Filter 4:* Following a two-week incubation period, the researchers re-evaluated the data. Finally, all material, including video recordings, was reviewed and analyzed to find input for the next intervention session and input for the program itself.

The collected data from each session mainly consisted of researcher notes and generated material from the first filter, in addition to other material generated through specific templates that were designed to tap into the participants' tacit knowledge. During within-case analysis (Eisenhardt, 1989), the researchers spent extensive time reviewing the data in order to become adequately familiar with it, as recommended in the literature (e.g., Boyatzis, 1998). The incubation period between Filters 3 and 4 allowed the researchers to distance themselves from the material in order to gain a new perspective (Tan et al., 2015) when re-evaluating the data during the final filter. Subsequent cross-case analysis (Eisenhardt, 1989) enabled the researchers to look for similarities and differences in the data.

Findings

Notes made by the researchers during the generative sessions mainly focused on three areas of interest. First was novelty: the researchers looked for indications and inspiration for aspects of training that were not known to exist in other training programs. For example, in Intervention 1, participants came up with an idea to send participants on a forest trip. The purpose was to take them out of a familiar context and conduct training in a novel place. Although this idea was not literally implemented in the program design, it highlighted the importance of the training environment. Second was noting down instances where participants voiced observations of each other's work. For example, in Intervention 2, the academics were asked to design a training program, and although each of them came up with different outputs, the interactions that followed were especially interesting, particularly when similarities and differences between their versions were discussed. Third were notes regarding material that was generated through specific exercises that had the purpose of prob-

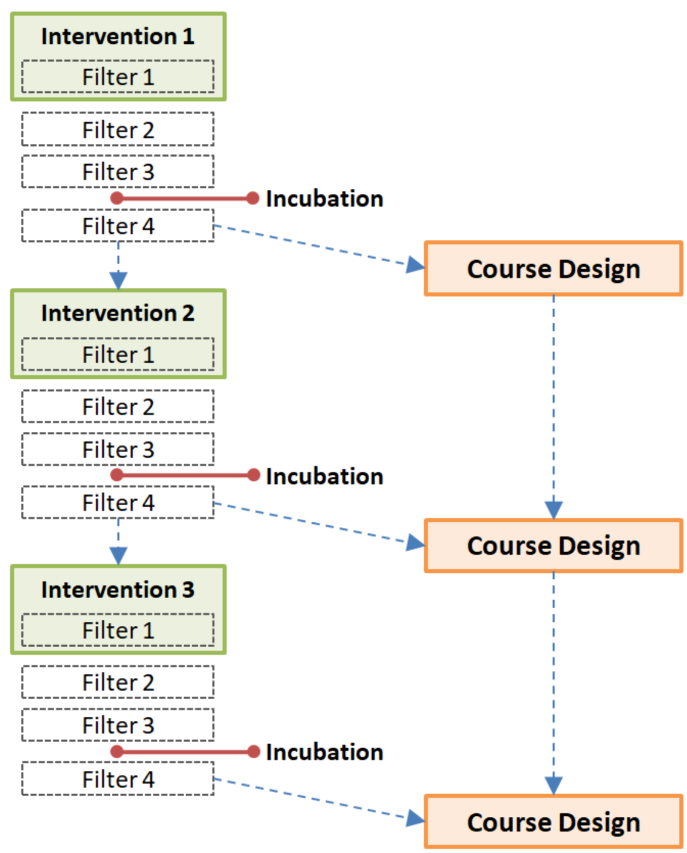

Figure 2. Process of analysis

ing the participants' tacit knowledge. For example, in Intervention 1, it was revealed that *trust* was an important factor for behavioural change, and the participants appeared to focus more on behaviour than cognitive processes, even though the latter were the foundation of the session.

Generated material

Through the research design, we identified which creativity-related processes were deemed important by innovators. Furthermore, we compared those results to creativity-related processes identified in the creativity literature as well as those deemed as important by the creativity academics in Intervention 2. Tables 3 and 4 provide overviews of the resulting lists.

The two tables reveal notable differences that highlight the importance of including different stakeholders in the process. During Intervention 1, the focus was, as previously stated, more on behavioural aspects the innovators associated with creative work, whereas the academics in Intervention 2 focused more on the cognitive processes associated with creativity. The HR managers in Intervention 3 focused less on the content, but more on the format for training, the formalities, and the types of individuals who should be trained.

Feedback and validation sessions

Once the data from the three generative sessions had been analyzed, a first draft of the training program was developed. To further strengthen the program's ***robustness*** (Rasmussen et al., 2010), the draft was presented to academics with expertise in educational development and pedagogy. Their feedback was taken into consideration when developing the second draft of the training program. After an iterative process of program development, where both the output from the co-creation process and the output of an extensive literature research were considered, we finally designed the first edition of the Creative Awareness Training program, which focuses on enhancing creative awareness while emphasizing the creativity-related processes identified in the generative sessions using metacognitive teaching methods.

Table 3. Prioritized list of creativity-related processes from Intervention 1

Participant	First Priority	Second Priority	Third Priority
1	Cross pollination	Zooming	Openness
2	Not afraid	Curious	Communication
3	Curiosity	Ability to express	Reflection on own and others' behaviour
4	Motivation/curiosity	Trust	Scope
5	Facilitation	Framing	Pattern recognition
6	Suspension of disbelief	Encouraging	Communication approaches

Table 4. Prioritized list of creativity-related processes from Intervention 2

Participant	First Priority	Second Priority	Third Priority
1	Self-efficacy	Association skills	Persistence
2	Domain-specific expertise	Openness	Persistence
3	Cognitive fluency	Association skills	Self-motivation

Realistic Creativity Training for Innovation Practitioners: Know–Recognize–React

Dagny Valgeirsdottir and Balder Onarheim

Creative Awareness Training: Know–Recognize–React

The Creative Awareness Training program we have developed is a result of several previous research efforts, as described in Figure 1 and in the Introduction. Here, we will discuss the findings from our transdisciplinary study that contributed to the program design through co-creation. The training program focuses on enabling the active use of the metacognitive skill we have termed *creative awareness,* thus we named the program Creative Awareness Training (Valgeirsdottir & Onarheim, 2016). The three generative interventions resulted in prioritized lists of creativity-related processes deemed important by innovators (Intervention 1) and creativity academics (Intervention 2). After the data had been analyzed, the findings were compared to the literature to validate its importance.

When viewing the creativity-related processes, it became apparent that they could be categorized into four levels: cognitive processes, personality traits, social skills, and management skills. As a result, the overall conceptualization of the training program consists of four modules, each allocated to one of the levels. The module we have now developed is the first one, which focuses mainly on cognitive creativity processes. The second module will focus on personality traits that can be thought of as supporting the core cognitive creativity, thereby propelling the individual creativity. Modules three and four will take the social dimensions into account by focusing on team dynamics and the collective dimensions of creativity. We argue that individual creativity provides the building blocks on which organizational creativity and innovation are built, thus they are the focus of the first module which we have now developed. The resulting description of findings will therefore focus on the cognitive module of our Creative Awareness Training.

The processes related to cognitive creativity were allocated into six sessions, each focusing on training specific skills to manage those processes. The training is based on a model we have termed Know–Recognize–React. The model was formulated after an extensive literature review of the metacognition literature (Dunlosky & Metcalfe, 2008; Flavell, 1979; Nelson & Narens, 1990) and metacognitive approaches to teaching (Hargrove & Nietfeld, 2014; Mevarech & Kramarski, 1997; Schraw, 1998; Schraw et al., 2005). As introduced above, metacognition has three facets: metacognitive knowledge, metacognitive monitoring, and metacognitive control (Dunlosky & Metcalfe, 2008). These were the inspiration for the Know–Recognize–React model we implemented into our Creative Awareness Training program. We aspire to teach our participants about the creativity-related concepts and processes they should *Know* (derived from metacognitive *knowledge*) followed by specifically designed exercises for the participants to be able to *Recognize* (derived from metacognitive *monitoring*) those processes, and finally introduce strategies and tools in order for the participants to be equipped to *React* (derived from metacognitive *control*) appropriately in situations where they encounter said creativity-related processes. An example is where we teach participants about divergent and convergent thinking (Guilford, 1959) because they provide the cognitive basis of creativity in addition to the associative basis (Mednick, 1962). Participants learn about the different processes (*Know*), go through specific exercises to experience first-hand how the different processes work (*Recognize*), followed by reflecting discussions where they are equipped with examples of how these might materialize in the real world as well as knowledge about how to strategically work most efficiently when deploying the different cognitive activities (*React*). Moreover, participants are taught about how the planned process consists of sequential series of diverging and converging and subsequently the same Know–Recognize–React model is applied.

In addition to the creativity-related processes to be emphasized in the training, as identified in Interventions 1 and 2, the format of the program was designed to fit the output from Intervention 3, during which the HR managers provided their knowledge. Thus, the execution of the program was condensed (in opposition to distributed over time) and limited to two full working days including preparation time; this timeframe was a direct result of Intervention 3. The curriculum consists of learning material, which should be consumed before initiating the program but within the two-day constraint, as indicated by the results of Intervention 3. The HR managers also indicated that it would be beneficial to direct the training with new employees. In addition to the pre-consumed learning material, made as a result of feedback from Intervention 5, the program consists of specifically designed exercises and training material, which we developed while taking into consideration pedagogical aspects deriving from metacognitive teaching methods (Schraw, 1998). Those exercises are completed throughout the six sessions with each exercise focusing on different cognitive creativity processes that were deemed important to train through the transdisciplinary study (Interventions 1 and 2). The program design furthermore corresponds to what Scott and colleagues (2004) specified as the optimal format of delivering creativity training. We do build the training on a concrete theoretical foundation by teaching participants about the cognitive basis of creativity. Furthermore, the theoretical part is a substantial aspect of the training, first within the pre-consumed learning material and second within the actual training, where theory is taught followed by the specifically designed exercises, which do to some extent rely on real-world cases. The training takes place almost entirely within a co-operative learning environment, as validated in Intervention 4 and also recommended to activate metacognitive processing (Mevarech & Kramarski, 1997). Finally, all of the material is complemented with a diverse library of exercises and tools that participants both complete during the training and can subsequently utilize to maintain their training for a more long-term result.

We theorize that, through this cross-fertilization of metacognition into both the program material as well as the pedagogical approach, the creative awareness of individuals will be enhanced and they will be able to perform their creative work more efficiently and with more creative self-efficacy. Future research efforts include a controlled experiment following the three criteria for studying the effectiveness of creativity training programs (Valgeirsdottir & Onarheim, in press), as well as the development of modules two, three, and four of the Creative Awareness Training. Finally, our aim is to test the long-term effects of the training.

Conclusion

In this article, we have presented a novel research approach to develop relevant, rigorous, and realistic training. Furthermore, we have presented the resulting first module of our more extensive Creative Awareness Training program. Through our study, we hope to contribute to the fields of creativity and innovation research with these two aspects: an inclusive research approach resulting in the development of our program aimed at enhancing the creativity of innovators. Creativity is an important problem-solving skill at any level of the innovation process, and through our Creative Awareness Training innovators will be able to train their creativity and raise their creative awareness level. Creative awareness is an important metacognitive skill, being a crucial mechanism to enhance all stages of the creative process. If an innovator becomes able to "Know, Recognize, and React" to situations dictated by creativity-related processes, they will be able to understand what works and what does not work for advancing the creative process. In turn, that enables them to become more strategic about which actions are appropriate and at what time they are most usefully deployed. Thus, they are able to make use of strategies, methods, and tools not just as an automatic procedure but as a highly conscious and purposeful one. In time, we believe this will enable innovators to become more efficient when working within innovation processes as a result of having mastered recognizing elements that can either potentially hinder or advance their processes and subsequently reacting accordingly.

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Improving Internal Communication Management in SMEs: Two Case Studies in Service Design

Tuomo Eskelinen, Mervi Rajahonka, Kaija Villman, and Ulla Santti

> *"In most people's vocabularies, design means veneer. It's interior decorating. It's the fabric of the curtains and the sofa. But to me, nothing could be further from the meaning of design."*
>
> Steve Jobs (1955–2011)
> Co-founder of Apple and Pixar

Effective information management is a success factor for business growth, but small and medium-sized enterprises (SMEs) face challenges in transferring knowledge and information from one organizational unit to another. In this study of two case companies, participative business model development processes were designed to identify challenges and solutions in internal communication management. A service design approach based on CIMO logic (context, intervention, mechanism, and output) showed that the participative business model technique and process can identify problems and challenges in internal communication management, as well as in the prioritization of actions. The process is a creative service design process including both divergent and convergent phases. The process increased motivation among personnel to find solutions, encouraged communication, and created joint understanding on how to solve problems. The technique helped to bring tacit information into use.

Introduction

Service and product innovation is a knowledge-intensive process (e.g., Balasubramanian & Tiwana, 1999). It can be described as an information-transformation process where information is gathered, processed, and transferred in a creative way. Obviously, communication is a vital and basic need, but it is also an opportunity for service and product innovation. This latter aspect is particularly important when team members are separated by geographical distances or when they work in shifts. External communication is also important for successful product innovation (e.g., Mendelson & Pillai, 1999). Communication and collaboration are therefore identified as critical factors for successful product and service innovation management.

A crucial innovation management problem in a small and medium-sized enterprise (SME) is communication inside the company, between its departments (Katcher, 2017; Zeithaml, 1988). For example, poor communication management between sales or marketing and production departments causes delays in the delivery of products or services, or quality problems connected to the production process or the product or service itself. Likewise, process communication is important, whether it is external (e.g., communicating with a client) or internal (e.g., communicating within a service-providing organization) (Moritz, 2005).

Many technological solutions have been developed for improving communication management, including collaborative platforms and social media applications. Also, employees use instant messaging as an additional means reaching others in real time, although it has an interruptive nature so management should pay attention to the quality and content of employees instant messaging (Cameron & Webster, 2005). However, there are still very few practical examples of how these technologies have been successfully implemented in SMEs, and many employees recognize that they should be getting more value from these tools. The main purpose of information management technologies should be to help workers do their work. They should also support

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teamwork and increase innovation and productivity. In addition, management needs information to support their staff, to increase effectiveness, and perform their own job better (Hamilton et al., 2016; Heckscher & Adler, 2007). Effective internal communication is crucial for successful organizations because it helps strategic managers to engage employees and achieve objectives (Welch & Jackson, 2007).

Pervaiz (1998) stated that the most innovative companies are those that manage to create appropriate cultures and climate that nurture innovation and creativity. Moreover, innovativeness with open organizational culture and market orientation has positive effects on organizational performance (Deshpandé & Farley, 2004; Deshpandé et al., 2000). Effective internal communication may increase the synergy effect with employees as ambassadors and improve company's marketing and public relations functions (Nielsen & Thomsen, 2009). Varey (1995) noticed that internal marketing may considerably increase competitive effectiveness by continuous improvement and culture change processes and also wondered what tactics and mechanisms may be used to translate information.

In this article, we describe our study of the challenges and solutions in internal communication management in two case companies. After developing the companies' communication processes, we inspected the effects on the company's organizational culture caused by the issued changes. We used service design and business model development approaches, and we tested how these approaches can be used in the context of internal communication challenges. We claim that business model tools can be used in a service design process. There are certain advantages in using service design and business model approaches instead of, for example, the business process management approach, which emphasizes improving performance by optimizing a company's business processes. Both service design and business model approaches are more multidimensional: they include customer and user perspectives in addition to the company's views. Furthermore, they include elements of conceptualization/social construction (through idea generation and selection), development or design (including design of better internal processes), and implementation of changes (Morelli, 2002; Nisula, 2012; Osterwalder & Pigneur, 2010). In other words, they both contain divergent and convergent phases, as typical in service design (e.g., Moritz, 2005).

Business model tools may help industrial companies to better utilize the insights of their own business processes and internal communication – and those of their business customers – and to design integrated solutions that correspond with their customers' needs (Ojasalo, 2017). The business model canvas by Osterwalder and Pigneur (2010) can be applied to cover both the industrial company´s viewpoint (value capture) and its customers' viewpoint (value creation) (Ojasalo & Ojasalo, 2015). Interaction and co-production are essential elements of the service logic business model canvas, introduced by Ojasalo and Ojasalo (2015). According to Ojasalo (2017), the key questions relate to how to facilitate the interaction between the company and its customers, what the customer's mental models of interacting with the company are, and how the company can support the customer co-production and the interaction between the company and the customer. The service logic business model canvas includes a specific block on interaction and co-production, which is connected to internal communication. However, internal communication in this context has not been the focus of other studies, which appears to present an obvious gap of knowledge.

Design thinking in our study means that problems and opportunities are framed from a human-centred perspective, trying to engage potential users and stakeholders, and we use visual methods to explore and generate ideas (e.g., Brown, 2008, as cited by Kimbell, 2011). Our research questions are:

1. How can SMEs overcome the challenges of internal information management by involving all the stakeholders necessary for a successful service design process?

2. How can service design tools and processes, such as participative business model techniques, be used in the identification of communication management problems and solutions inside SMEs?

Our approach to answering these questions and the resulting findings are described below. First, we introduce the project from which the two cases were drawn and the service design tools and methods that were applied to each case company. We also describe our analytical approach, which used CIMO logic (context, intervention, mechanism, and output). Next, we present and discuss our findings. Finally, we offer conclusions, with a particular emphasis on their implications for SMEs.

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Methods

This research is based on two case studies where participative business model techniques were used as part of an innovation process to identify internal communication challenges and solutions. The participative process and tools used include interviews, discussions, and brainstorming. We believe that these methods can be used to uncover explicit user information and reveal tacit knowledge from the employees (Sanders & Dandavate, 1999).

The case companies in this research were participants in the Pake Savo project (Eskelinen et al., 2017), which is a joint project of Finnish universities: the South-Eastern Finland University of Applied Sciences XAMK and the Savonia University of Applied Sciences. The case companies were selected from about 20 SMEs who participated in the Pake Savo project. The selection criteria were a need to develop internal communication and willingness to design a participative development process. The two-year project began in 2015 and was financed by the European Social Fund. The purpose of the project was to help SMEs located in the Northern Savo (Eastern Finland) to start or develop their service business. In today's rapidly changing business environment, SMEs need to develop new innovative service concepts. Therefore, Pake Savo project aimed to advance new business creation and productivity in the participating SMEs, which were from the service and manufacturing industries. The Pake Savo project arranged two training packages on service design for the SMEs. The training was developed and delivered by the two participating universities of applied sciences. Selected external experts also delivered training modules. Related to the training sessions, each company carried out a development project associated with each company's service business. In these development projects, the participants learned, for example, how to apply the training on service design methods and the business model approach to their companies.

Several of the companies used the InTo business model analysis tool (into.savonia.fi), which was developed in Savonia (see Kajanus et al. 2014), to select the development project or to prioritize key development targets. The Into analysis enables personnel to be involved in and committed to the process from the beginning. The selected themes of the development tasks included the development of new service concepts or service products, better customer service or internal processes, and more fluent information flows. The development projects showed that, in a customer-oriented company, effective internal communication is essential. In other words, only if internal communication processes work well, can a truly customer-oriented service approach become a reality. The shift from a product-oriented company to a customer-oriented company cannot succeed without a major change in the organization's culture. As a part of the training (i.e., the Training Programme on Service Design, Pake Savo, 2015–2017), the SMEs applied a service design approach in their company to develop their businesses, especially to develop new innovative products and services. Typical development topics for service design are process development and development of offerings, and development of marketing, sales, organization, or business strategy (Koivisto, 2014; Miettinen & Koivisto, 2009). Development of new offerings means that they differ from the previous ones, for example, from the point of view of the operating model, customer value, revenue logic, target group, or user experience.

In the two case SMEs, internal communication management was identified as a key problem. Participative business model techniques were used in the identification of communication management problems. Business model techniques can be used in a business design process of an SME aiming to create strategies, reasoning, insights, and improvements in communication. Kajanus and colleagues (2014) have presented a process for business model creation by using multiple-criteria decision support techniques and portfolio analysis. These techniques were now applied to facilitate the communication development process. The researchers designed and realized separate innovation processes in the two case companies together with the management teams and a development group consisting of employees.

Company A produces high-quality furniture and components for different purposes, such as ergonomic furniture constructed hygienic Corian material. Before the training started, the researchers asked the company to fill in a questionnaire, which contained questions on development needs. Development needs and challenges were also identified and discussed during a site visit. Based on the results, internal communication between production, marketing, and delivery of products was identified as a key challenge. A business model development process was designed and performed during 2015. The process contained five steps: i) context design, ii) idea generation, based on interviews of the CEO and application of the web-based Savonia InTo innovation tool (into.savonia.fi), iii) evaluation of ideas against two criteria: improvement of internal communication and management of customer relationships, iv) core index analysis, according to Kajanus and colleagues (2014), and v) discussions with personnel on the results and actions (Figure 1). The general theme was defined as developing internal communication and customer relationships management as part of the company's business model. The ideas could be connected to customer needs, to the value produced for the customer, sales channels, development and maintenance of customer relationships, key resources, key activities, or key partners. Company A's goal is to find the ideas and actions that will enable them to deliver products to the customer in an efficient and timely manner. The process produced 28 ideas and 23 comments on those ideas. All company personnel participated in the generation of the ideas and the evaluation and discussion of the best ideas. The best ideas were selected with the help of the core index method and discussions. The goal was to bring the best ideas into practice.

Company B also participated in the Training Programme on Service Design (Pake Savo 2015–2017), filled in the questionnaire on development challenges and needs, and hosted a visit by researchers. Visits were undertaken by service design and business development researchers from the participating universities. The company is highly innovative, as indicated by its 100 patents. It designs, manufactures, and markets repair equipment and measuring systems for collision-damaged vehicles. Based on the results of the analysis, internal communication between production, marketing, and sales departments was identified as a major challenge in developing the company´s business model. Communication errors have led to many problems, such as delays in the information chain from client to production. When clients need architectural or other changes, for example a change of equipment, information needs to reach all people in the production chain very quickly. The internal communication development process was designed and implemented in 2016. It contained context and participant definition, idea generation with six questions on internal communication challenges, idea evaluation against selected criteria, core index analysis of results according to Kajanus and colleagues (2014), and a workshop to discuss the results and decide actions. There were four evaluation criteria for ideas in the evaluation phase: i) improvement of internal communication, ii) feasibility, iii) increase in productivity and turnover, and iv) cost-benefit value. The process created 32 new ideas and four complete evaluations against the evaluation

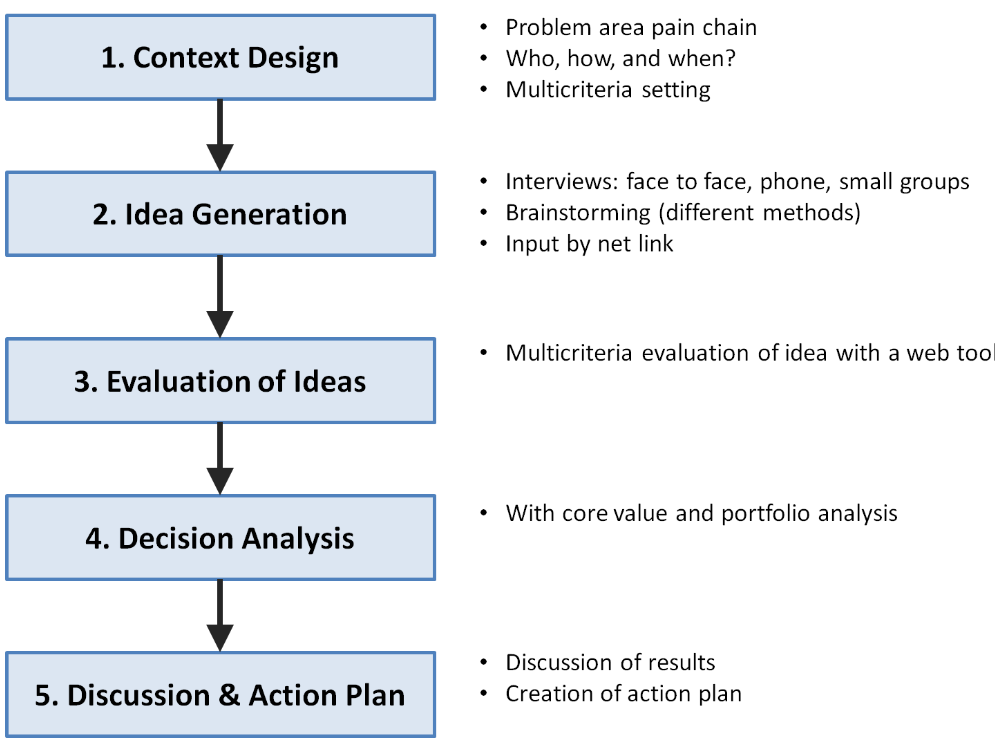

Figure 1. Participative development process for business model techniques (adapted from Kajanus et al., 2014)

criteria, all of which were analyzed with core index analysis. The ideas were prioritized according to their core index.

Next, CIMO logic (context, intervention, mechanism, and output) was used to describe and analyze the two case studies (Denyer et al., 2008). The purpose of working with CIMO logic is to produce design propositions for enabling understanding and insights of the explored phenomena. A proposition with CIMO logic is formed as follows: for a problematic *context*, use some specific *intervention* that will invoke some generative *mechanisms* that in turn will deliver the desired *outcome*. The propositions thus not only inform what should be done in a specific situation in order to create a specific effect, but more importantly, they offer insight on *why* it happens (Denyer et al., 2008; Proper et al., 2010). CIMO logic has been used, for example, to analyze public health sector innovations (Batterham et al., 2014; Proper et al., 2010) and to establish a set of design principles to foster the development of teacher communities in secondary education (Brouer et al., 2012).

Findings

The main results of the study are novel methods and innovative tools to identify information management problems, and testing of these tools with solutions piloted in practice in SMEs. The solutions brought about improvements in information management in the case companies. In addition, changes and developments in the communication management and organizational culture are observed and discussed. The main results of the analysis based on CIMO logic (context, intervention, mechanism, and output) are presented in Table 1.

The results were obtained, in the case of Company A, one year after the development process had been finished, and, in case of Company B, only one month after. For this reason, the responses from Company B are interpreted as “goals” in comparison to Company A, whose answers are interpreted as “actualized” items. Company A established a computer-based solution that aims to facilitate more effective communication between the departments, and the solution has been tested and piloted with some clients.

Table 1. Results of CIMO logic analysis (Denyer et al., 2008) of the participative business model techniques for development processes in Companies A and B

CIMO	Company A	Company B
Context	A Finnish company offering tailored wood and composite based products, such as acoustical elements for loudspeakers. Challenges lie in developing internal communication between production, marketing, and delivery of products	A Finnish company that designs, manufactures, and markets repair equipment and measuring systems for repairing collision-damaged vehicles. Challenges lie in internal communication between production, marketing, and sales departments.
Intervention	Business model development process to find new ideas and solutions.	Development process to find ideas and solutions to develop internal communication.
Mechanism	A business model development process: context definition, idea creation with interviews and web link, multi-criteria idea evaluation with a web based tool, portfolio analysis of results and workshop	A development process with six questions on challenges in internal communication, idea creation in a workshop, external expert visit to accelerate creation of new ideas, idea evaluation with a web tool, multi-criteria evaluation of ideas, portfolio analysis of results, and a workshop
Output	Two solutions were identified and put into practice. A WhatsApp application was tested and found useful.	Prioritized list of actions. A decision was made to improve, test, and pilot an internal communication system.

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For example, if the marketing department discovers changes in the customer needs, they communicate directly with the production team, and the development and management departments. Or, if the production team discovers that they need more material, they communicate with the planning department. Company A reports that they have already achieved higher efficiency with one larger client. Previously, a project delivery with a client was delayed due to many changes in customer specifications. In this case, when the client needed different colours, and at the same time, the project developer could not keep the original schedule, dealing with these changes caused a cost of €20,000. Moreover, because of improvements in the internal communication process, clients receive their invoices more quickly and efficiently. Furthermore, the new communication system has proved to be efficient in several other situations. Previously, the information chain was not functioning well, but now, because of the new information system, the information reaches the right recipients in an intelligent way. For example, after the information comes from the client, it is delivered directly to the machining department unit where the changes to the product are done. Another example is when the marketing department recognizes a need to change or improve a product, they negotiate with the client and inform the production department. All information is delivered with a centralized system using email, WhatsApp (www.whatsapp.com), and an implementation system developed by the company. The process applies lean information management to eliminate wasting of time and to increase speed (George, 2002).

The management of Company A claims that the "most important ideas may rise from the most silent worker". The development process was useful because tacit information was made available and the silent workers' ideas were recognized and heard. The management group encourages new ideas to improve internal communication. On the other hand, there has been some resistance against changes. Moreover, not all workers have had the same communication tools, which have delayed the improvement process in internal communication. In the future, Company A will look for new training activities that target further time and production efficiency as well as improving efficiency in internal communication management.

In Company B, internal communication was chosen as the development topic because many challenges had been faced. Information did not reach the right people at the right time. As a very important development question, Company B's goal was that the managers and bosses should know at all times what is happening in the field and are aware of any reclamations. The company estimated that a substantial improvement was gained as a result of the development process. As another result, an internal communication system was identified as a solution and it now has been piloted with users. Since only a short time has passed after the development process was finished, not all the decisions to improve internal communication have been put into action. Company B's experience of the development process has been that it committed and inspired employees and made the problems clearer and more understandable to all. The next step would be putting the solutions into practice. Also, the personnel's motivation has increased, and it seems that all are doing their best to improve internal communication. There is more discussion and awareness of the challenges. Overall, the development process helped to gain a joint insight on what the problems, challenges, and solutions are in internal communication management. Moreover, it was important to find tacit ideas from the silent workers. As the next step, development needs were identified in order to design and put into practice a digital information management system. For this purpose, Company B and Company A also shared knowledge on solutions as part of the Training Programme. Company B also has decided to develop their meeting routines.

Conclusion

Service design was in the focus of the training programme in which both Companies A and B participated. As feedback, the companies stated that service design methods offer many new possibilities and the training programme increased their knowledge on service design methods as well as collaboration. Of particular importance was the identification of customer needs with service design tools and methods. In addition, tacit information from the employees was brought into practical ideas and solutions with the InTo tool based on a business model approach.

This research presents a systematic business model process, which is efficient in the identification of communication management problems and challenges. Second, it presents the application of the process into two practical cases that illustrate how improvements of internal communication management challenges can be realized in practice. This systematic process and the practical cases create effectiveness and enhance new innovations in the ways how internal communication is managed in SMEs. However, in particular, applying participative business model techniques in the context of

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service design has proven to be a very successful approach. Consequently, the process becomes more multidimensional, customer-oriented, and includes both divergent and convergent phases, and creativity, as typical to service design (e.g., Moritz, 2005). For example, Company B's new product innovation has started from customer needs, namely the need garages have for a productive and fluent service chain when they offer services to their clients who bring cars to the garage for repairs. For garages, the need is to "get the job done easily". The customer feedback on the new product has been very good. Company B actively thinks about customer needs and even the "needs of the customers of their customer".

The service design training programme was linked to real business needs and resulted in measurable improvements in internal communication in the participating SMEs without forgetting the customer perspective. The process including participative business model techniques increases interaction inside the company; interaction is needed when creating more user-oriented services (Miettinen & Koivisto, 2009). The process also increased motivation of the personnel to solve both internal problems and customers' problems.

All SMEs could potentially benefit from the findings of this research. Problems in internal communication management cause many difficulties, which even affect the final customer and end-user satisfaction. Practical case examples also demonstrate that cost-effective solutions are available to improve internal communication management. Better communication management helps workers and executives perform their work better and faster, solve problems more quickly, as well as deliver more value for their customers.

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Tuomo Eskelinen, PhD, works as an RDI Advisor at the Savonia University of Applied Sciences in Finland. His background is in Environmental Sciences, and his expertise and research interests include sustainable value networks, development of business partnerships, and sustainable business models. He organizes research, development, and innovation processes with enterprises and other organizations, with scientists, end users, and customers, from idea generation to business models development and commercialization. He has participated in more than 20 EU-funded projects in the fields of forestry, energy, food, water safety, and processing. He is experienced in performing and coordinating interdisciplinary, international, large-scale research projects, workshops and training.

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Using Artificial Intelligence and Web Media Data to Evaluate the Growth Potential of Companies in Emerging Industry Sectors

Andrew Droll, Shahzad Khan, Ehsanullah Ekhlas, and Stoyan Tanev

> *The world needs a better understanding of how to encourage innovation. And innovators need to get better at it. Sign me up.*
>
> Robert Metcalfe
> Co-Inventor of Ethernet and Founder of 3Com

In this article, we describe our efforts to adapt and validate a web search and analytics tool – the Gnowit Cognitive Insight Engine – to evaluate the growth and competitive potential of new technology startups and existing firms in the newly emerging precision medicine sector. The results are based on two different search ontologies and two different samples of firms. The first sample includes established drug companies operating in the precision medicine field and was used to estimate the relationship between the firms' innovativeness and the extent of online discussions focusing on their potential growth. The second sample includes new technology firms in the same sector. The firms in the second sample were used as test cases to determine whether their growth-related web search scores would relate to the degree of their innovativeness. The second part of the study applied the same methodology to the real-time monitoring of the firms' competitive actions. In our findings, we see that our methodology reveals a moderate degree of correlation between the Insight Engine's algorithmically computed relevance scores and independent measures of innovation potential. The existence of such correlations invites future work in attempting to analyze company growth potential using techniques founded in web content scraping, natural language processing, and machine learning.

Introduction

Efficient, intelligent tools to evaluate the growth and competitive potential of new technology startups and existing firms in a newly emerging industry sector would deliver valuable insight to stakeholders in many spheres: companies, entrepreneurs, governments at all levels, and investors. However, attempts to study such firms are typically hindered by a lack of sufficient information about the new business sector and the reluctance of the firms – especially startups – to openly share detailed information about their specific business intentions and their actual or potential competitive moves.

In this article, we focus on a sector that typifies these challenges: the emerging precision medicine sector of the healthcare industry. Precision medicine is a new medical approach that promotes the customization of healthcare with medical decisions, practices, and products that are tailored to specific patient groups or individual patients sharing the same treatment needs (Vicini et al., 2016). The tools employed in precision medicine include molecular diagnostics, imaging, and analytics that are used to select appropriate and optimal therapies based on the context of a patient's genetic makeup or the results of other molecular or cellular analyses. The establishment of the precision medicine sector has enabled the emergence of new startups focusing on the development of such types of tools as well as the engagement of incumbent medical companies in the exploration of similar business opportunities.

The case of technology startups in this business area is of particular interest. They are expected to win large business deals by competing to create value in the precision medicine value chain through the development of platforms that could be used to interpret and analyze data, thereby contributing to better diagnoses.

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However, it is very difficult to study such firms due to the insufficiency of information and their own discretion about their specific competitive differentiation strategies. The present article suggests a research approach that could deal with such information insufficiency and discretion by using keyword-based web search techniques and public information that was made available online by third parties. This approach represents an original attempt to study companies' potential for innovation by tuning a developing, innovative competitive intelligence platform for the task of evaluating media perceptions of competitive advantage and growth potential in the precision medicine space.

The article is structured as follows. First, we further describe precision medicine, including both the scope of opportunities in the sector and the challenges of studying the potential growth of companies within it. Then, we describe our research design and the Gnowit Cognitive Insight Engine, which we used for the analyses of the firms' growth potential, innovativeness, and competitive actions. After presenting and discussing the results of these analyses, we offer conclusions and identify future areas of research.

Background: The Precision Medicine Sector

The sphere of precision medicine represents a dramatic departure from prior perspectives on innovation in healthcare. Whereas prior medical treatments have widely been based on targeting an "average patient" in the general population, precision medicine describes an approach in which individuals' measurable unique characteristics across a multitude of genetic, medical, and lifestyle-related parameters define how treatments should be administered (White House, 2015). Instead of rigid prescribed treatment regimes, precision medicine offers highly customizable treatment programmes tailored to provide much more efficient individualized care (Wikipedia, 2017). In 2015, to support innovation in precision medicine, the United States government launched the Precision Medicine Initiative and the affiliated All of Us Research Program (allofus.nih.gov). The All of Us program aims to aggregate data from a population of one million volunteers, including data on genomes, microbiomes, and epigenomes. The data collected by All of Us will be federated in a large database accessible to researchers for scientific purposes.

It is expected that broad effects on healthcare will manifest from developments in precision medicine. Better understanding and use of individual genetic signals, more customizable medical devices, and personalized diagnoses based on deep analyses of patient data represent some of the foremost aspirations with regard to potential for advancement in this field. As the field develops, new business models will emerge from companies of all sizes in their efforts to bring products to market. These models will be enabled by technological advancement and innovation in spheres including molecular diagnostics, medical imaging, and big data analytics (Knowledge@Wharton & SAP, 2016).

Business researchers and practitioners are increasingly focusing on studying the potential growth of specific companies in the precision medicine sector as well as the innovation strategies that could make a difference in terms of potential patient health outcomes. For example, a recent study provided ranked 23 biopharmaceutical companies based on the extent to which they are driving innovation in precision medicine (Amplion, 2016). The ranking is based on: i) how many precision medicine products a company currently markets; ii) the percentages of the company's recent clinical trials that involve biomarkers; iii) the number of novel oncology drugs the company has in its pipeline; and iv) the number of proprietary biomarkers the company is using in its clinical trials.

Another recent study listed a number of technology companies that are likely to be leaders in precision medicine for years to come (Borukhovich, 2016). Their selection was based on their innovation potential due to their listing in the Crunchbase company database (www.crunchbase.com). The companies are not ranked in any way because they are at a relatively early stage of their lifecycles. The list of companies allows the analysis of emerging value propositions in the precision medicine technology sector. However, the early stage of the companies suggests that many of them are in a stealth mode that does not allow them to share the details of their specific competitive strategies and the analysis of their growth potential. Thus, business analysts, researchers, and potential investors are left to their own means and to information that is available online in examining the growth, innovation, and investment potential of such early-stage firms. The situation highlights the increasing need to develop appropriate competitive intelligence tools and techniques that could use publicly available online information about newly emerging firms to evaluate their growth potential and competitiveness.

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Research Methodology

The methodology used in the research for this article was structured around using keyword-based web search and real-time media monitoring techniques to analyze publicly available online data about companies to be studied. This approach was taken in combination with the use of the Gnowit Cognitive Insight Engine (Gnowit engine, www.gnowit.com), a platform that uses machine learning to analyze the magnitude of similarity between corpuses of documents. The Gnowit engine was principally developed by Andrew D. Droll, Lead Data Scientist at Gnowit Inc., by building on the expertise of Shahzad Khan, CTO of Gnowit Inc.; together, they are the first two co-authors of this article. The research methodology was shaped in collaboration between Gnowit and the two other co-authors who are researchers at the University of Southern Denmark. There are at least two substantial prospective advantages associated with focusing on information that is provided online by third parties. First, in many cases, this is the only valuable information that is available about early-stage companies. Second, information provided by third parties is expected to be unbiased with respect to the scarce marketing information provided by the companies themselves. With this research, we aimed to determine whether this type of data, when combined with a machine learning approach, could produce useful insight into companies' growth potential.

We started our study by examining the relationship between the intensity of online media discussions focusing on the business growth of companies in the pharmaceutical and biotechnology industries, and the empirical ranking of their innovativeness such as provided by independent third-party sources. To this end, the Gnowit engine was employed to analyze textual data collected from online publications that are available throughout the Internet. Gnowit's crawler architecture automatically collects news article content from more than 8,000 publications, including the largest newspapers in the world, and extending down to a number of small regional and local papers and outlets. All of this data was available to the Gnowit engine during our experimentation.

To analyze this aggregated data using the Gnowit engine, we have developed a Boolean query designed to extract articles relating to industry growth in the precision medicine sector. The specific keywords were selected through a close examination of recent books such as *Get Backed* (Baehr & Loomis, 2015), *The Lean Startup* (Erik Ries, 2011), and *Business Model Generation* (Osterwalder & Pigneur, 2010). The final query combined a variety of composite keywords focusing on:

> ***Market growth*** ("Market size" OR "market growth" OR ((fast OR growing) AND market) OR "market conditions" OR "attractive market position" OR "unique market position" OR "emerging market" OR "niche market" OR "new market" OR "market confusion" OR "market ambiguity" OR "market share" OR "market leader");
>
> ***Business growth*** ("Growth potential" OR "business growth" OR "growing momentum" OR "growth strategy" OR "fast-growing company" OR "growing sales" OR "sales growth" OR "revenue growth" OR "ramp up sales" OR "growing market demand" OR "growing customer demand" OR "scale up" OR "boosting revenue" OR "increasing revenue" OR "greater product sales" OR "new service income" OR "minimize costs" OR "new revenue streams" OR "sustainable revenue" OR "stimulate growth" OR "growth indicators" OR "growth factors" OR "competitor growth strategy" OR "competitive strengths" OR "business strengths" OR "increasing return" OR "increasing income");
>
> ***Competitive differentiation strategy*** ("Business differentiation" OR "competitive differentiation" OR "market differentiation" OR "competitive advantage" OR "business advantage" OR "unique value proposition" OR "unique selling point" OR USP OR "competitive position").

The three composite keywords above were connected through a logical OR operator. The resulting larger composite keyword was connected through a logical AND with the terms "precision medicine" and "personalized medicine". The final result was a query, or "search ontology", which we labelled Precision Medicine Growth (PMG). The Gnowit engine is usually used to compare companies on the basis of their relationship to certain specific single signals; however, Gnowit's systems permit comparisons across several signals at once, meaning it can classify a company's media coverage in a true ontological fashion. This query served as a heuristic to isolate a set from several document sources that were initially pre-collected and maintained by Gnowit: Canadian Online News, Government – Med Sources, Tech Startup News – USA, and US Online News.

The Gnowit engine used the PMG query as an instruction to perform the following steps:

1. Retrieve the collection of the latest published articles that match the query heuristic.

2. Tokenize the content of these articles in a way that leads to the construction of a set of textual terms and numeric weightings for each term. This step transforms each document into a term-weighting vector.

3. Add the individual document term-weighting vectors together to create an aggregate term-weighting vector for the entire PMG heuristic (henceforth called the "PMG vector").

4. Store this aggregated heuristic vector as a retrievable context vector that can be used to provide numeric strength-of-similarity analysis with other similar heuristically-developed aggregate vectors.

The capability described above was leveraged as follows. We used as a case study the sample of 23 companies that were ranked by (Amplion, 2016) in terms of their innovativeness in precision medicine. For each of these companies, we developed an additional individual Boolean query designed to act as a heuristic returning articles that relate to that company name alone. Subsequently, we submit an instruction to the GCIE that requests the computation of an aggregate heuristic vector (in the same way as described above for generating the PMG vector) for each company name heuristic, and returns back a numeric value corresponding to its strength-of-correspondence to the initially calculated PMG vector. As a result, each company now has a numerical strength-of-correspondence measure that could be used to evaluate its potential growth in the precision medicine sector. We refer to this measure as the PMG Gnowit score.

In the second part of our work, we applied the above methodology to another research context – real-time monitoring of the competitive actions of the same companies. This specific choice of the second research context was motivated by the insights from a closer examination of the way Gnowit search engine operates. The Gnowit engine does not search across all articles on the Internet; rather, it only searches across those articles that were published in a period starting two weeks in the past and ending at the present moment– a limitation imposed by the company's infrastructure cost constraints as a small startup. The time period for the search is a moving time window that looks only two weeks back in time. In this sense, it might be best suited for the monitoring of most recent events or actions corresponding to firms' current competitive strategy. That is why we constructed a new search ontology focusing on competitive actions. The construction of the new ontology was done on the basis of insights from McInnis (2008) and Grimm and colleagues (2006). The query corresponding to competitive actions in precision medicine (CAPM) took the following form:

> (("Asset development" OR "Resource adjustment") OR ("Brand awareness" OR "Brand loyalty") OR ("Intellectual property" OR "Product Development" OR "Product improvement" OR "Product design") OR ("Competitive strategy" OR "Competitive advantage" OR "Competitive market position" OR "strong market position" OR "Time to market" OR "lower entry barriers" OR "Joint ventures" OR "Economies of scale" OR "economy of scale") OR ("accelerate adoption" OR "market adoption" OR "viable business model" OR "solid business model" OR "category leader" OR "customer engagement " OR "customer involvement" OR "User driven") OR ("Demonstrate performance" OR "Development center" OR "Exceed goals" OR "Expand adoption" OR "Deliver more value") OR (Funding OR "Global expansion" OR "Global reach" OR Grow OR growth OR "product availability" OR "Strength management" OR "technology support") OR (Innovation OR "innovation at a fraction of the cost" OR "cost effective innovation" OR "innovation at lower cost" OR "Product innovation") OR ("join executive" OR "join leaders" OR "joint solution") OR ("launch product" OR "launch solution" OR "lead emerging technology" OR "lock-in" OR "lower cost ownership") OR ("new alternative" OR partner OR "partner program" OR "partner trusted provider" OR "powerful capabilities" OR "rapid development" OR "rapid innovation" OR "reduce costs" OR "regional expansion")) AND ("precision medicine" OR "personalized medicine")

The replication of the search methodology on the basis of the CAPM ontology resulted in a CAPM vector that was used to measure the competitive activity of PM firms. We refer to this measure as the CAPM Gnowit score.

Research Findings

The methodology described in the previous section allowed us to evaluate the correlation between Amplion's innovation ranking and the PMG Gnowit score, which corresponds to the intensity of online media discussions of companies' focus growth in the precision medicine sector.

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Ranking firms by PMG Gnowit scores

Table 1 lists the 23 companies that were ranked by Amplion (2016) in terms of their innovativeness in the precision medicine field. The table also includes their innovation ranking and two sets of PMG Gnowit scores corresponding to their growth potential in the precision medicine sector. The results in Table 1 compare the firms' innovation ranking and the PMG Gnowit scores for two different two-week time periods: December 13 to 17, 2016, and January 20 to February 3, 2017, 2017. Figure 1 illustrates the PMG Gnowit scores for all 23 firms in the second time period. The numerical difference in scores between these periods is due to shifting coverage of these companies and of the precision medicine space over time. Variance of this type is normal because it is based on current news coverage. The main element of interest is that of scores relative to each other across different companies (though this will also shift as news coverage changes, for example in response to product announcements or releases or company financial announcements).

Figure 1 shows that the highest scores in the second period belong to Johnson & Johnson, followed by Merck, Pfizer, Bristol-Myers Squibb, and Roche. Table 1 also reveals substantial differences in the scores between successive time periods depending on the degree of online discussions associated with a particular firm. For example, there was a 10-times increase in Roche's PMG Gnowit score in the second time period. Such radical changes could be explained by the nature of the Gnowit search engine, which focuses on monitoring online discussions that happened in the last two-week period. It could happen then, for example in a time of reporting impressive (or disappointing) quarter results, that the name of a specific company has been involved in an unusually high number of online discussions in the past two weeks, leading to an unusually high PMG Gnowit score.

The above discussion leads to three important points:

1. The suitability of the Gnowit engine for a specific search will depend on the context of the research project. In our present case, we are trying to evaluate the growth potential of firms in an emerging industry sector. It is clear that the evaluation of such potential should not be based on online information collected over just two weeks. The evaluation of the growth potential should extend the methodology by including the possibility to accumulate or integrate results from multiple successive two-weeks periods in order to cover a longer period of time, such as six months, a year, or longer.

2. The evaluation of the growth potential cannot be based on the quantitative results alone and should incorporate additional qualitative semantic textual analysis. The Gnowit search platform offers additional analytical capabilities that allow for sentiment analysis to indicate the degree to which the online discussions are associated with positive or negative statements. This feature was not included in the present study and will become the subject of future studies.

3. The two-week search window feature of the Gnowit search engine suggests that it could be more directly applicable to the real-time monitoring of firms' competitive actions because such actions might have a real-time competitive effect on competitors.

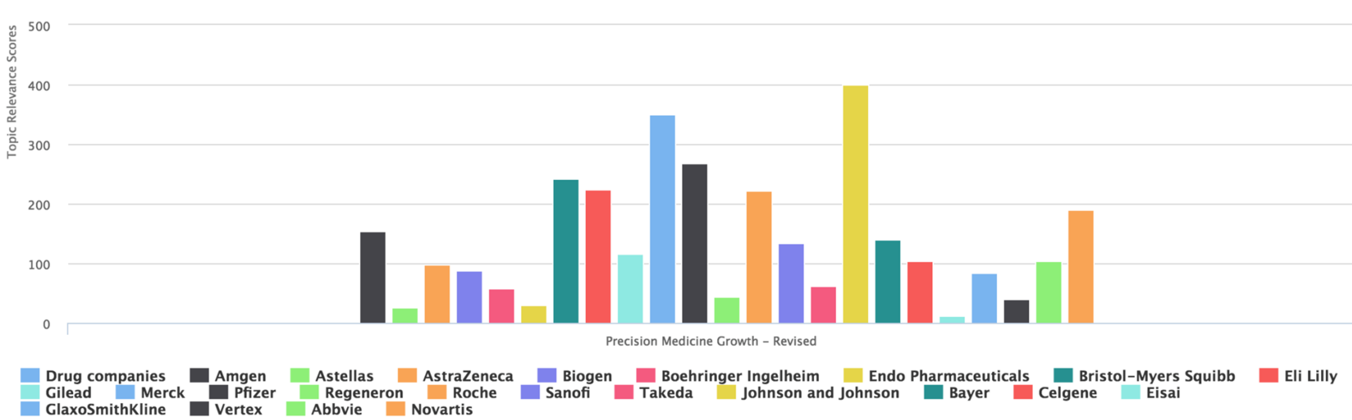

Figure 1. Ranking of the 23 innovative drug companies in terms of their PMG Gnowit scores. The graph was automatically generated by the Gnowit search platform.

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Table 1. Innovation ranking of 23 established firms in the emerging precision medicine sector (Amplion, 2016) together with their PMG Gnowit scores corresponding to the intensity of online discussions about their growth potential in the PM sector

No.	Company Name	Innovation Ranking	PMG Gnowit Score Period 1	PMG Gnowit Score Period 2
1	Novartis	0.67	23.11	190.76
2	Roche	0.56	20.97	222.49
3	AstraZeneca	0.46	11.99	98.69
4	Pfizer	0.43	30.18	268.36
5	GlaxoSmithKline	0.38	6.54	83.73
6	Boehringer Ingelheim	0.35	6.74	57.82
7	Merck	0.31	21.46	349.55
8	Celgene	0.30	13.02	103.31
9	Eisai	0.29	2.23	11.11
10	Johnson & Johnson	0.25	24.89	410.11
11	Sanofi 6	0.21	10.94	134.62
12	Lilly	0.18	21.08	224.97
13	Bristol-Myers Squibb	0.18	33.59	245.19
14	Bayer	0.15	13.98	140.34
15	Amgen	0.14	9.40	154.13
16	Astellas	0.13	4.26	25.70
17	Abbvie	0.13	13.08	104.33
18	Takeda	0.11	3.02	61.55
19	Gilead	0.10	19.94	116.29
20	Endo	0.09	7.77	29.41
21	Biogen	0.06	16.15	88.25
22	Vertex	0.03	4.05	40.08
23	Regeneron	0.02	5.35	43.22

Relationship between innovativeness and PMG Gnowit score

For the first measurement period, the Spearman correlation coefficient between the innovation ranking and the PMG Gnowit score was 0.38 ($p < 0.1$). In the second period, it was 0.43 ($p < 0.05$). Even though the statistically significant correlation coefficients correspond to a moderate degree of correlation, their degree of statistical significance may vary across different time periods depending on the intensity of online discussions in a specific time period. Nevertheless, a moderate or high statistically significant degree of correlation suggests the existence of a relationship between a firm's PMG Gnowit score and its innovativeness. Such relationship will obviously depend on the specific terminological composition of the search ontology. We can claim, however, that our growth potential search ontology seems to have worked well in detecting a relationship between growth terminology and innovativeness. The existence of such relationship suggests that the methodology based on our growth potential search ontology could be applied to study the growth and innovation potential of early-stage companies for which there is no competitive intelligence information. To test this assumption, we will apply the methodology to the precision medicine technology companies that were identified as promising by Borukhovich (2016).

Applying the methodology to studying the innovativeness of new precision medicine technology firms

In this section, we present results of the PMG Gnowit score ranking of a sample of 29 new technology-based firms in the precision medicine sector (Borukhovich, 2016). Table 2 shows the results for the PMG Gnowit scores of these firms in the second time period. Only 6 firms had a nonzero score (Table and Figure 2). The rest of the firms did not have any online coverage in this particular period.

The previous results about the correlation between firms' innovativeness and their PMG Gnowit scores, together with the results shown in Table 2, were expected to provide us with a basis to estimate the degree of innovativeness of the firms shown in Figure 2. In addition, the results shown in Table 2 would suggest that there was no innovative activity by most of the firms. Such conclusions, however, should be subjected to the same considerations as the ones made in the previous sections. First, the results as such do not allow such conclusions unless we have performed online measurements across multiple successive two-week periods, which would allow us to estimate the aggregated effect of the online discussions over a longer period of time. Second,

Table 2. PMG Gnowit scores of 29 innovative new technology firms in the precision medicine sector

No.	Company Name	PMG Gnowit Score
1	KineMed	0
2	Advanced Cell Diagnostics	0.43
3	Syapse	0
4	Centrillion Biosciences	0
5	Epic Sciences	0.32
6	Ignyta	1.77
7	Eve Biomedical	0
8	Sctheranostics	0
9	Kuraoncology	0
10	Genoptix	1.07
11	Precipio Diagnostics	0
12	Inform Genomics	0
13	Miramix	0
14	Enumeral Biomedical	0
15	Population Diagnostics	1.08
16	Genterpret	0
17	Rosetta Genomics	0
18	Translational Software	0
19	4D Healthware	0
20	Everist Health	0
21	GenomOncology	0
22	Cellular Dynamics Int	7.60
23	Kailos Genetics	0
24	Microarrays	0
25	PHIGENIX	0
26	Precision for Medicine	0
27	NeoDiagnostix	0
28	Genomind	0
29	Permedly	0

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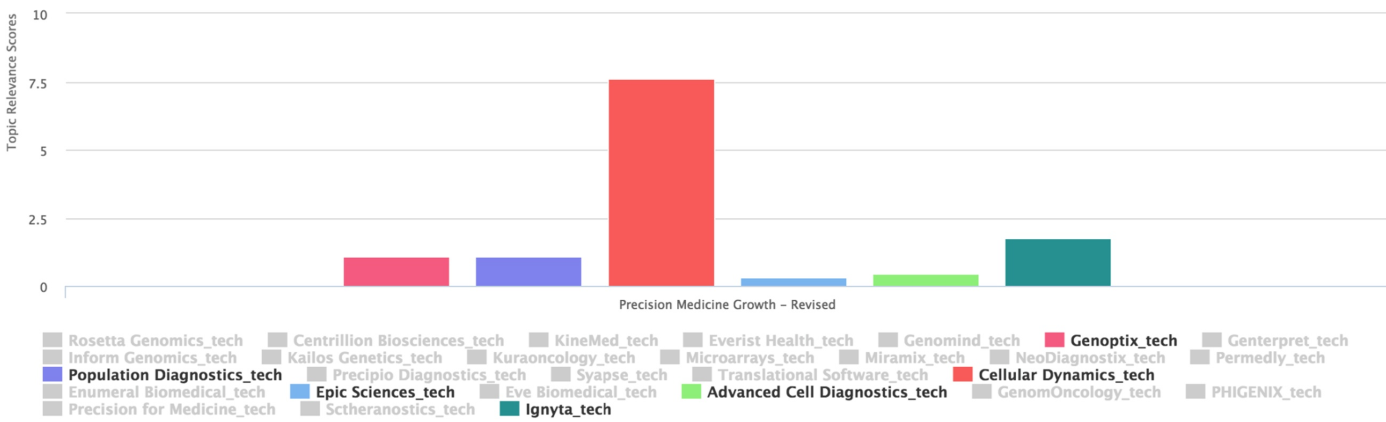

Figure 2. Ranking of the six new technology firms with growth-oriented online coverage in the second time period

the functionality of the Gnowit search engine could be better suited to search ontologies focusing on monitoring real-time competitive moves of firms in an emerging industry sector.

Applying the methodology to studying the competitive actions of precision medicine firms

In this section, we apply the competitive action search ontology to study the real-time competitive actions of the same two samples of firms that were studied in the previous sections. Table 3 shows the list of the firms together with their innovation ranking (the same as Table 1) and their CAPM Gnowit scores. Figure 3 provides ranks the firms in terms of their CAPM Gnowit scores (measuring coverage related to competitive advantage in the precision medicine space). The correlation coefficient between firms' innovativeness and their CAPM Gnowit scores is 0.439 ($p < 0.05$), which suggests again a moderate degree of correlation.

The visible degree of correlation between the firms' degree of innovativeness and their CAPM Gnowit score again offers the opportunity to use the competitive action ontology to estimate the innovation potential of the 29 new technology firms in the precision medicine sector (Borukhovich, 2016).

Table 4 lists 5 out of the 29 firms that had some online coverage in the second time period; the rest of the firms did not have such coverage. Figure 4 shows the five firms in terms of their CAPM Gnowit scores. The results show that Cellular Dynamics Int (CDI) has the highest CAPM Gnowit score. Table 5 provides details of three documents referring to CDI that were found to be most relevant in the search. The relevance of a particular online document within the context of the specific search project is defined by a relevance score calculated by the Gnowit search platform on the basis of the semantic correlation of the content of the document and the

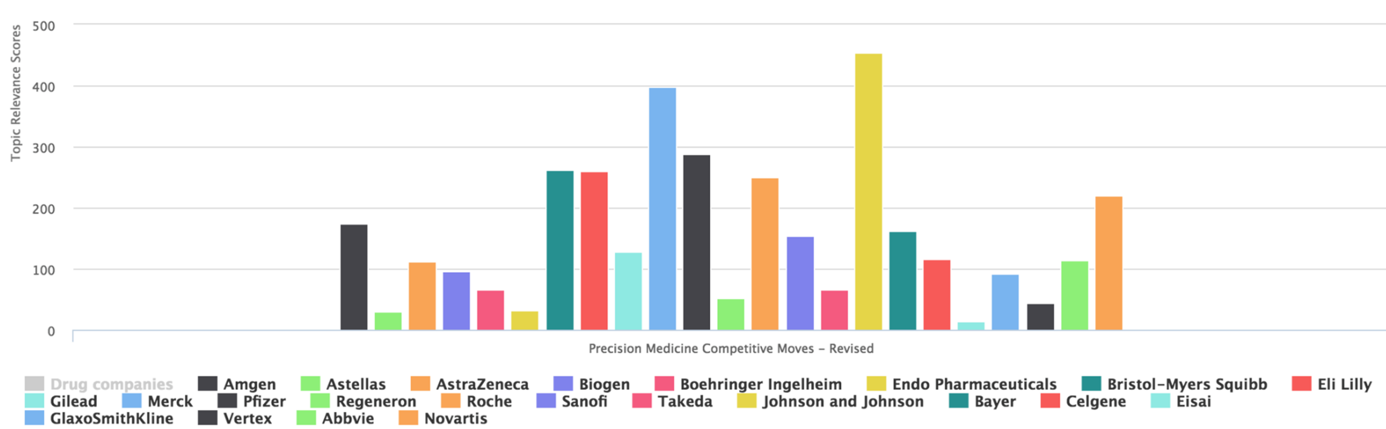

Figure 3. CAPM Gnowit score ranking of the 23 drug firms operating in the precision medicine sector over the second time period

Table 3. CAPM Gnowit scores of the 23 drug firms over the second time period

No.	Company Name	Innovation Ranking	CAPM Gnowit Score
1	Novartis	0.67	219.75
2	Roche	0.56	250.44
3	AstraZeneca	0.46	111.12
4	Pfizer	0.43	288.43
5	GlaxoSmithKline	0.38	91.83
6	Boehringer Ingelheim	0.35	65.84
7	Merck	0.31	398.48
8	Celgene	0.30	116.32
9	Eisai	0.29	13.16
10	Johnson & Johnson	0.25	453.22
11	Sanofi 6	0.21	153.83
12	Lilly	0.18	260.89
13	Bristol-Myers Squibb	0.18	261.63
14	Bayer	0.15	161.82
15	Amgen	0.14	174.08
16	Astellas	0.13	29.78
17	Abbvie	0.13	113.93
18	Takeda	0.11	66.28
19	Gilead	0.10	127.46
20	Endo	0.09	32.90
21	Biogen	0.06	95.72
22	Vertex	0.03	43.62
23	Regeneron	0.02	52.53

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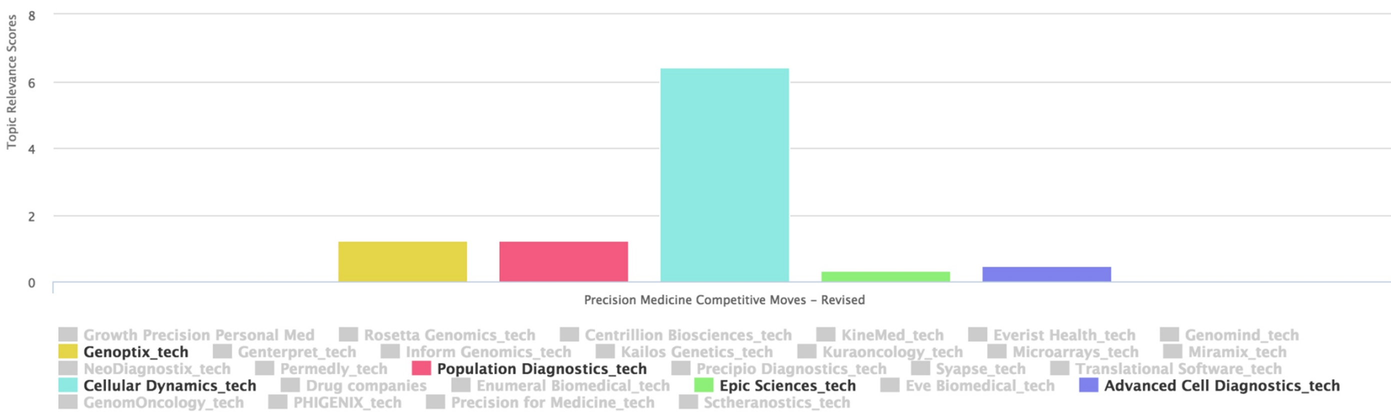

Figure 4. CAPM Gnowit score ranking of five new technology firms operating in precision medicine sector

Table 4. CAPM Gnowit scores of five innovative new technology firms in the precision medicine sector that had online coverage focusing on competitive actions

No.	Company Name	CAPM Gnowit Score
1	Cellular Dynamics Int (CDI)	6.41
2	Genoptix	1.23
3	Population Diagnostic	1.23
4	Advanced Cell Diagnostics	0.46
5	Epic Sciences	0.34

Table 5. List of the online documents about Cellular Dynamics Int (CDI) with the highest relevance for the search focusing on competitive actions

No.	CDI-Related Document	Relevance Score and Web Link	Context
1	2015 FDA Science Forum Emerging Technologies, May 27 – 28, 2015 U.S., Food and Drug Administration	Document relevance score: 100 Web link: tinyurl.com/yatn6oy2	CDI used by United States Food and Drug Administration (FDA) scholars as a reference in a comparison with another major drug supplier
2	Global Stem Cell Therapy Applications & Treatment Analysis & Trends 2016-2025: $1.55 Billion Growth Opportunities/ Investment Opportunities – Research and Markets	Document relevance score: 62 Web link: tinyurl.com/y8tdnul3	CDI included in the list of leading companies in stem cell therapy and treatment analysis
3	FDA Cooperative Research and Development Agreements (CRADAs)	Document relevance score: 7 Web link: tinyurl.com/yc8464ja	CDI project listed as one of the projects supported by the FDA R&D program

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search ontology. The specifics of the semantic correlation are out of the scope of this article; however, for a high-level view, the scores are derived in the following way. First, Gnowit's search engine is queried for the articles matching the search ontology terms. These articles are analyzed using natural language processing techniques to extract a characteristic linguistic profile for the associated query in recent media coverage. Then, when plots are generated, the same process is performed for companies themselves. Articles relating to each company are retrieved from Gnowit's search engine via query, and these are analyzed to produce a characteristic linguistic profile for the companies. Finally, a similarity measure is applied to generate linguistic proximity scores between media coverage relating to the search ontology terms and the companies undergoing analysis. By comparing these scores across companies using the same underlying search ontology terms, we obtain relative measures of company discussion in the media.

The information provided in Table 5 offers just a glance of how the Gnowit search engine could be used to monitor the competitive actions of new firms in an emerging industry sectors. The validation and automation of such search projects needs more systematic research studies, which will be the subject of future efforts.

Conclusion

This article presented the results of a research study focusing on adapting and validating the use of a business intelligence tool – the Gnowit Cognitive Insight Engine – for entrepreneurship and innovation research. The focus of the study was on uncovering the exploratory and analytics potential of the existing functionality of the Gnowit search engine and the ultimate objective is to articulate insights that could further enhance its potential as a competitive intelligence tool for entrepreneurs, investors, managers, and entrepreneurship scholars. The results provide a first glance at this potential and highlight opportunities for future studies in this direction.

In particular, we hope in the future to be able to expand the time interval for news coverage to be analyzed beyond Gnowit's current two-week scope. A longer time period will allow more comprehensive and significant evaluations of the significance of the types of measures that we examine in this article. Also, this avenue could open the possibility of developing an engine to monitor changes in companies' potential over time, potentially kept up-to-date in real time, which could provide true utility to researchers and companies in the wild. As the current time restriction is primarily one borne of resource constraints, investments in Gnowit's technology may permit this type of exploration in the future. Finally, additional research opportunities are presented by the capabilities of Gnowit's technology not yet explored by this article. In particular, in this article, we only examined comparisons between companies using search ontologies consisting of a single search term – in effect, doing one-dimensional analyses of the companies' relative media impressions. The Gnowit ontology engine supports ontologies with dozens of terms, which might permit the generation of significant, multi-dimensional comparisons and analyses of companies' impressions in the media across many signals of interest.

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Keywords: startup growth potential, artificial intelligence, entrepreneurship, precision medicine sector, online textual data, analytics, business intelligence

A University–Industry Collaborative Entrepreneurship Education Program as a Trading Zone: The Case of Osaka University

Koichi Nakagawa, Megumi Takata, Kosuke Kato, Terumasa Matsuyuki, and Toshihiko Matsuhashi

> *Collaboration is important not just because it's a better way to learn. The spirit of collaboration is penetrating every institution and all of our lives. So learning to collaborate is part of equipping yourself for effectiveness, problem solving, innovation and life-long learning in an ever-changing networked economy.*
>
> Don Tapscott
> Business executive, author, and consultant

Two complementary problems are that busy practitioners find it difficult to access academic knowledge and university students lack practical experience. University–industry collaborative education is a potential solution for both of these problems by bringing together theoretical insights from universities and experiential know-how from industry. However, university–industry collaborative education has not been sufficiently studied to offer clear frameworks and mechanisms to foster effective knowledge exchanges between these two groups. In this article, we propose the metaphor of a "trading zone" as a potential analytical framework for implementing this method of education. Applying this framework to the analysis of a university–industry collaborative education program, this study proposes that the exchange of knowledge between students and practitioners is the essential learning experience and that it is made more meaningful by the heterogeneity between students and practitioners. The shared language provided by the program and those who deliver it make the exchanges efficient, and the temporary and extraordinary nature of the program accelerate those exchanges. Here, we analyze the case of Osaka University in Japan to illustrate the framework and develop associated propositions to encourage further study and validation of the framework.

Introduction

To foster entrepreneurship and its skills, both formal education in novel theory and experiential learning in practical fields are needed Academic theory gives us rational and logical ways of thinking about technologies and management, and experience tells us how they work in practice (Etzkowitz, 2004; Gibb, 1996; Ollila & Williams-Middleton, 2011). However, conventional education programs provided by universities typically focus only on the theoretical side. Thus, in recent years, universities have tried to introduce experiential learning to help students understand how theories can be applied to the real world (Gibb, 1996). Among these efforts, university–industry collaboration, which encourages two-way interactions and learning, holds great promise (Dooley & Kirk, 2007; Perkmann & Walsh, 2007) because university students can obtain rich and insightful experiential know-how from industry-side participants and practitioners can gain theoretical knowledge from students. Furthermore, the effectiveness of university–industry collaboration for entrepreneurship education is enhanced particularly through project-based learning (Blumenfeld et al., 1991), where both university students and industrial practitioners jointly tackle a social, business, or technological problem. Examples of entrepreneurship education through university–industry collaboration can be seen in several universities in diverse countries (Etzkowitz & Leydesdorff, 2000; Lundqvist & Williams-Middleton, 2013).

Although past studies have indicated that university–industry collaboration can be an effective approach to entrepreneurial training because it can realize the combination of university theory and practical experiences, we know little about how participants truly interact each other, how exactly this approach facilitates entrepreneurship, and how we can improve its performance. In short, the field lacks a validated framework to support the effective implementation of the approach. Hence, the objectives of our study were: i) to propose a potential framework that can capture the university–industry collaboration approach to entrepreneurship education and ii) to provide qualitative and quantitative evidence of its effectiveness.

The rest of this article is structured as follows. First, we briefly review the relevant literature on entrepreneurship education and university–industry collaboration. Next, we introduce our method of insider action research and our research site: Osaka University, Japan, and its Technology Entrepreneurship and Commercialization program. Then, we present the results of our qualitative and quantitative analyses of the case. Through our discussion of the case analysis of the program at Osaka University, we next apply the metaphor of a "trading zone" (Galison, 1997) as a useful framework for and entrepreneurship education program based on university–industry collaboration. Finally, based on the case and its analysis, we offer several propositions to encourage further study and validation of the framework.

Literature Review: Entrepreneurship Education and University–Industry Collaboration

Considering their technology bases, sophisticated problem-solving methods, and skillful and ambitious students, universities can undertake more initiatives in innovation (Etzkowitz, 2004; Etzkowitz and Leydesdorff, 2000). As Etzkowitz and Leydesdorff (2000) explain the role of the university in their triple helix model, nowadays the industry–government dyad is insufficient in realizing industrial innovation, and a university–industry–government triad is needed to address the needs of today's knowledge society.

Given the new role for the university in relation to industry and government, facilitating and encouraging entrepreneurship becomes an important part of its mandate (Gibb, 1996; Ollila & Williams-Middleton, 2011). Traditional management education focuses on the administration of hierarchical organizations and it tends to foster risk-averting decision making, and students as well as practitioners have become used to this administrative way of thinking. In contrast, the goal of entrepreneurship education is to develop skills and attributes that enable the realization of opportunity (Rasmussen & Sørheim, 2006). Thus, to undertake a new and expanding role in innovation, universities have started their own entrepreneurship education programs (Barr et al., 2009; Janssen et al., 2007; Meyer et al., 2011).

Among the many and diverse approaches to entrepreneurship education, Dooley and Kirk (2007) consider university–industry collaboration to be effective and well suited to entrepreneurship training because, by nature, it combines the strengths of business entities with those of research and education institutions. As Gibb (1996) discussed, in entrepreneurship education, opportunities for experiential learning are needed for learners to understand realistic approaches to innovation and to nourish and challenge their minds. Ollila and Williams-Middleton (2011) proposed that the integration of conventional university education and a new experiential approach is desirable because they complement each other. The former encourages the problem-oriented thinking and the latter fosters solution-oriented thinking, and both are beneficial in innovation activities.

Although research into university–industry collaboration for educational purposes is limited, a few studies have investigated how and why it contributes to entrepreneurship training. For example, Cyert and Goodman (1997) used organizational learning theory to developed a basic framework for examining university–industry collaboration in education. They argue that the fundamental benefit of collaboration between university and industry is learning from each other. The university can obtain methods and practices used in industry and industry can study the university's technology, and such interactions should be facilitated to enhance innovation. Thus, Cyert and Goodman argue, the educational program should be designed to foster mutual learning between the university and industry. Indeed, in past qualitative studies, such interactions between university members and industrial practitioners were often discussed as a chief characteristic of university–industry collaboration as an educational approach (Borrell-Damian et al., 2010; Dooley & Kirk, 2007).

The literature lacks detailed investigations regarding the exchange of knowledge through university–industry collaboration for the purposes of education, especially in the context of entrepreneurship. Past studies have largely been qualitative or conceptual have only described entrepreneurship education through university–industry collaboration in general. The research area lacks empirical evidence of the effect of the knowledge exchange on the capabilities of participants, and we do not have a framework that shows how it can be achieved and facilitated university–industry collaboration within an education program.

Given this gap in theoretical and practical knowledge, we set out to examine the case of Osaka University by asking: *How can participants in an entrepreneurship education program based on university–industry collaboration effectively exchange heterogeneous experiential knowledge with each other despite differences in their disciplines, skills, and motivations?*

Research Method: Insider Action Research at Osaka University

This study is based on an inductive case study of the Global Technology Entrepreneurship and Commercialization (G-TEC) program at Osaka University from 2011 to 2016. Considering our question has an open-ended, "asking-how" nature, an explorative case approach is a suitable approach because it can generate insights from the in-depth description (Eisenhardt, 1989; Yin, 1994). Data covering the G-TEC program was gathered from insider action research (Brannick & Coghlan, 2007; Roth et al., 2007). We chose the insider action research method because being part of an extraordinary setting helps the researcher to precisely capture and describe what happens in within it. Two of the authors have engaged in developing the G-TEC program from the beginning and have worked as program facilitators in every year of its operation. The other two authors joined the study as observer–facilitators just after the start of the program. The last author analyzed the G-TEC program objectively as an external observer. This team structure was adopted to ensure the richness of the description and endow diverse viewpoints, while maintaining objectiveness.

In addition to the qualitative analysis, we executed statistical analysis of a set of questionnaires completed by G-TEC participants in 2012 and 2013. We first asked participants to complete the questionnaire before G-TEC program, to understand their initial capability in technological venturing. Then, we asked them to complete the questionnaire again after the program, to check what capability they had acquired through the program. We gave questionnaires to all 50 participants during those two years, and 48 (96%) completed both "before and after" questionnaires. Within the questionnaire, we asked program participants about their perceived capability in technology venturing. Respondents were asked to answer each item using a five-point Likert scale that ranges from "1: I do not have that skill at all" to "5: I have that skill a great deal". Although we note that the resulting answers only provide the participants own perceptions about their capability, they nonetheless give an important indication of the *changes* in the participants' perceptions. Considering the emotional, psychological, and motivation-based nature of entrepreneurship (Drucker, 2014; Timmons & Spinelli, 1999), a change in perception is a useful indicator of the participant's progress.

The Global Technology Entrepreneurship and Commercialization (G-TEC) Program

This study analyzes the G-TEC program at Osaka University as a research site. The program is a typical example of university–industry collaboration for entrepreneurship education. It has operated on a yearly basis since 2011. It is a short-term program that is delivered over the course of 2 weeks (8 hours per day over 10 days) with a course fee around $2,500 USD. About 20 people participate in one instance of the program; thus, more than 100 students have completed the program. As its name indicates, the Technology Entrepreneurship and Commercialization program is designed to endow in its participants a capability around fundamental methods of technology entrepreneurship and commercialization.

Although the fundamental direction and methodology have been kept unchanged, the details of the program have been refined step by step. The program was initially openly advertised to both for university students and lecturers and corporate practitioners, and the number of applications regularly exceeded the capacity of the program. Rather than simply accept participants on a "first come, first served" basis, the program facilitators decided to select participants through interviews in which they ask about the motivation, basic problem-solving skills, and past experiences of the applicants. Every year, the program staff have carefully balanced the diversity of participants at the time of recruitment, resulting in a nearly equal overall representation of university-based participants such as students or lecturers (44%) and participants from industry (56%). With each category, the participants have diverse experiences and skills. The students and lecturers have come from all kinds of schools including the social sciences, natural sciences, and humanities; the practitioners have come from engineering, manufacturing, sales and marketing, and the general administrative departments of several industries including the pharmaceutical, information technology, and electronics industries.

The G-TEC program was designed to integrate technological incubation and entrepreneurship education. It was co-designed by the office for university–industry collaboration and Professor Ashley Stevens from Boston University, who was then President of the Association of University Technology Managers. The design of the program recognizes that experiential learning is needed to develop true entrepreneurial skills and spirit, and such an educational grounding has often accelerated the commercialization of technologies. During the morning sessions of the program, the participants take classes about technology assessment, fundamental steps toward commercialization, entrepreneurship, market and competition analysis, intellectual property rights, technology development methodology, business model generation, financial forecasting, and funding strategies. In the afternoon, participants are challenged to make a technology assessment report and a strategic plan to achieve product completion and commercialization. At first, potential technologies within the university are provided by university–industry collaboration. A few university-based participants and a few industry-based participants form a cross-boundary team and tackle the assessment of one technology. More than 60% of the entire program is dedicated to building the assessment and commercialization plan report, including the relevant coursework as well as practical activities for commercialization and a field-based survey. We believe that the G-TEC program provides a suitable context to consider the theoretical model of an education program based on university–industry collaboration, because it includes its standard (but advanced) characteristics such as intellectual property assessment, technology marketing and licensing, proof of concept, business modelling, business planning, and so on. Given that the G-TEC program is designed from the benchmarking of the programs that were recognized as successful examples of university–industry collaboration, such as the University of Texas Austin and Boston University, it can be considered a tailored replication. The program was slightly modified in order to fit with the context of Japan, where people are often less inclined toward risk taking and opportunity seeking.

Details of the G-TEC program
In the G-TEC program, university-based participants learned from discussion with the business participants the reality of how to develop technology and products in private companies. They learned the importance of financial estimation, how cost and speed are crucial to market success, and how market demand is essential in commercialization. In addition, participants from the university also learned that sometimes a project must be abandoned if it proves unfeasible in terms of time, cost, or product quality. In the G-TEC program, the technology assessment often resulted in a tragic conclusion: scarce opportunities in the market, excessive development costs, or the discovery of more desirable technology. However, such conclusions nevertheless gave insights about the methodology of commercialization. Participants learned that the choice of technology is a vital aspect of reaching the market.

Project-based, experiential learning facilitated those practical methods and the understandings about the reality of technology commercialization. Students not only observed the practitioners' approaches but also tried to replicate them in the G-TEC program's joint project. By doing so, students learned those methods, which became tools that they could draw upon in the future. As one student participant noted in 2011:

> *"The greatest change for me was to first consider the business model when evaluating a potential technology. In the past, I only saw technology from its own technological viewpoint. However, after the collaboration with practitioners in G-TEC, I came to think of the business aspect. When I listened to the conference presentation about certain technological areas, every participant exclusively discussed technological features and challenges, while I considered who would be customers of that technology."*

In addition, university-side participants learned the importance of humanity in entrepreneurial activities. In the business entities, contrary to the students' perspective, members act not only with the rationality of business but also with human feelings. Humanity becomes rather important to realize good progress in a project, because it endows members with a project mission that tackles a social problem, and it also facilitates in-depth communication with members that have diverse backgrounds (Hindle, 2007). Participants were often motivated by such a noble mission and realized good progress in developing the commercialization plan for the technology. Students were impressed by the challenging spirit that industry-side participants showed in the projects. Their high motivation guided teams toward the goal intensively, and students learned that this is a key success factor in entrepreneurial activities. As one student participant noted in 2013:

> *"I was impressed by the attitude of the practitioners toward the work. From their behaviour, I recognized the importance of the shared vision and the mutual trust within a project team. Conversation is critical to assess and develop the potential of the technology, and the vision and trust emerge from such conversations."*

Participants from the industry side, on the other hand, learned theories and frameworks about technology development and commercialization from the instructors and university-based participants (Galloway & Brown, 2002). This information included management theories for strategy, finance, and marketing as well as theories and methods about technological innovation and venturing that were provided in the courses of the university. By obtaining each knowledge component of technology and venture development, they captured the panoramic view of the venturing process from technical seed generation to commercialization. Industry-side participants began to change their everyday behaviour at work in response to the insights from the theoretical viewpoint they received in the G-TEC program. As one corporate participant noted in 2013:

> *"I'm working as an engineer in a company. In this program, I learned skills to develop technology from the customer's viewpoint. I studied marketing theory and methods as well as market-oriented technology management in G-TEC. It was when I returned to my company than I truly understood the usefulness of what I had studied. I attended a technological conference held in New York as the company's representative. Although I had given presentations about our technology at past conferences, this time I found I could communicate with foreign engineers about how to solve their business problems using our technologies. Furthermore, I realized that I could collect information about potential markets for our technology while at that conference."*

Corporate-side participants learned the power of adopting a different viewpoint. Within the program, students often threw them innocent questions about the nature of the technology, business, and corporation. From those questions, practitioners sometimes recognized that their thinking was biased by their surroundings, whether it was competition, customers, colleagues, or even their boss. They then found that they could change the technology development policy or commercialization plan based on the insights from those innocent questions. Such occasions made them understand the power of diversity, which generates various ideas from different viewpoints. As one corporate participant noted in 2013:

> *"Group work with Osaka University students was exciting. Through the discussions I had with them, I recognized that my thinking, which was derived from my usual work in the company, was a little bit biased. The curiosity of the student-side participants gave me a hint. They asked questions about things that I thought of as common sense. But through the debate with students, I found that, for some of them, this way of thinking was not rational. Based on that experience, I learned the importance of doubting common sense and searching for new ideas from a wide range of viewpoints."*

The role of program faculty and facilitators
The G-TEC program facilitators, which consist of three university lecturers and two office staff, represent the infrastructure of the program. The university lecturers have academic expertise in the areas of business management and have taught innovation management in the business school. One of them has a key role in offering in-class education in the morning sessions and is supported by the two other lecturers. The office staff basically work as facilitators of the technology assessment project, drawing upon their rich experience in developing technology and businesses in addition to academic credentials and experience in university–industry coordination. They also provided introductory instruction for team projects, including how to study, how to cooperate with each other, how to use relevant tools and utilities, and how to foster the spirit required for technological commercialization.

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In the words of one of the facilitators, the faculty and facilitators work to create a "shared language" for the diverse participants. The faculty and staff recognize that a shared language was important to execute the project work, particularly because it helped the participants share their ideas about technology commercialization more efficiently. Introductory instruction, as well as subsequent lectures, contributed to building up both a shared language and a shared cognition of participants.

Aside from delivering the classroom material and providing introductory information, the faculty and staff tried to limit their interference with each team's project work – they allowed the learning to emerge from the participants' experiences. Both success and failure provided opportunities for learning, so the faculty and staff simply provided opportunities for experiential learning and – as much as possible – left it to the participants to decide which opportunities to pursue and how. Only when the participants seemed "stuck" and were unable to progress with a project did the faculty or staff enquire about the problem and offer advice on how to improve the situation.

Findings

Independence and temporary nature of the project

Some participants emphasized that the program allowed them to experiment and explore opportunities that would not have been possible in their companies or university. Many of them joined the program because they were interested in new methodologies of commercialization or business development, but found it difficult to apply those methodologies in their company. After completing the program, many felt they had the knowledge, confidence, and legitimacy to try new things once they returned to their usual work, as one corporate participant noted in 2014:

> *"I really enjoyed it. I could try what I could not do in my department. In G-TEC, I could act freely, without considering any risks and stakeholders in the company. I could focus my effort and attention on research and planning of the project. I could apply some methodologies that I had learned not only in the program, but also from books I had read in the past."*

The independence and temporary nature of G-TEC program seemed to encourage a spirit of exploration among the participants. The program gave them a sense of freedom because it is totally independent from their everyday work or study, thus participants could act without thinking about how they might be judged by their boss, colleagues, customers, or human resources department. In addition, the short, two-week duration of the G-TEC program was beneficial. Although participants kept in touch with each other after the program, it basically did not affect their usual work, other than the small number of cases where participants have formed a venture business after the program. Furthermore, the limited timescale made it easier for companies to send participants, whether it was the employees needing to obtain permission to take time off work for the program or joining the program at the behest of their bosses.

Finally, the independence and temporary nature of the program had a positive effect on the participants' motivation. Participants recognized it as a special occasion to study novel ideas and new ways of thinking, apart from their usual work. They felt compelled to take advantage of a unique opportunity.

Changes in capability

To confirm our qualitative observations, we next examined the results of our survey of participants in the G-TEC program. As explained above, the survey asked participants about their perceived capability in technology venturing, both before and after the program. Table 1 shows the quantitative comparison of the perceived capability change between student participants and practitioner participants. The results show that students and practitioners benefitted differently from the program: the university students gained more business skills and external collaboration skills than participants from the industry, whereas industry participants obtained more technology development and commercialization methodology skills and more skills for team building than the university students. In other words, student participants learned in the program what they could not learn in their usual university education: business skills and external collaboration skills. Practitioner participants, in contrast, obtained knowledge about the methodology of technology development and commercialization, which are taught formally in universities. Furthermore, the data indicated that practitioners understood the importance of a diversity of team members for generating unique ideas. These quantitative results provide evidence that the exchange of knowledge worked in the G-TEC program, and they are in line with our qualitative observations.

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Table 1. Comparison of the capability change between 18 student participants and 30 practitioner participants of the G-TEC program. The bold and shaded text highlights the group with the larger improvement in perceived capability for each category.

	Students				Practitioners			
	Pre - G-TEC	Post- G-TEC	Δ	Sig.	Pre - G-TEC	Post- G-TEC	Δ	Sig.
Skills for technology development and commercialization								
Technology development	2.277	2.631	0.353	(0.401)	2.757	3.433	**0.675***	(0.013)
Product development	2.117	2.789	0.671†	(0.075)	2.562	3.500	**0.937*****	(0.000)
Technology assessment	1.888	2.684	0.795*	(0.046)	2.242	3.466	**1.224*****	(0.000)
Commercialization process	2.000	2.894	**0.894***	(0.031)	2.393	3.233	0.839**	(0.004)
Skills for business								
Market analysis	2.222	3.105	**0.883***	(0.035)	2.575	3.400	0.824**	(0.003)
Customer targeting	2.055	2.947	**0.891***	(0.032)	2.636	3.100	0.463†	(0.083)
Basic skills for business	2.555	3.000	**0.445**	(0.228)	2.727	3.000	0.273	(0.362)
Skills for team building								
Inclusion of inventors	2.166	2.263	0.096	(0.795)	3.000	3.500	**0.500†**	(0.076)
Managing diversity	2.388	2.684	0.295	(0.505)	2.606	3.166	**0.560†**	(0.057)
Skills for collaboration with external institutions								
External communications	1.833	2.421	**0.587***	(0.027)	2.575	2.933	0.357	(0.208)
Use of mentors	1.611	2.315	**0.704†**	(0.077)	2.606	3.033	0.426	(0.126)
Collaboration with incubators	1.388	1.947	0.559†	(0.080)	2.272	2.833	**0.560†**	(0.052)

Significance in T-test (all two-tailed): † <0.1, * <0.05, ** < 0.01, *** < 0.001.

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Discussion

From the case analysis, we confirmed that knowledge exchange actually happened between university students and practitioners within the G-TEC program, and that it is promoted by program facilitators and the program's "special atmosphere" and conditions of this short-duration program. Students learned managerial skills and gained an entrepreneurial mindset from their interactions with the practitioner participants and by observing their behaviour and ways of thinking. The practitioners learned academic knowledge and frameworks for entrepreneurship from the students and the faculty. This knowledge-level interaction could be considered as one of the core contributions of education through university–industry collaboration. To build up entrepreneurship skills and spirit, both theoretical and experiential learning are desirable (Dooley & Kirk, 2007; Ollila & Williams-Middleton, 2011). In this sense, this form of collaborative education is effective because it can provide experiential know-how for students and theoretical knowledge for practitioners. Based on past conceptual studies (e.g., Cyert & Goodman, 2007) and our evidence that the exchange of knowledge actually occurred in education through university–industry collaboration, we offer the following proposition:

> ***Proposition 1:*** Education for technological entrepreneurship based on university–industry collaboration is characterized by the exchange of knowledge among different groups: faculty members, practitioners, and university students.

In examining this exchange of knowledge through our observations of the G-TEC program, we apply the metaphor of a "trading zone". The basis of the metaphor is anthropological studies by Galison (1997, 1999), who examined how different cultures are able to exchange knowledge in temporary projects. Galison found that members from different communities were able to exchange their knowledge despite having fundamental differences (Galison, 1997). To enact a trading zone does not require equivalence of interests or interpretations. Furthermore, even the permanence of relationships is not needed to work in a trading zone. Participants from different organizations coordinate their behaviours temporarily and locally, navigating their different norms and interests as needed (Kellogg et al., 2006; Vaughan, 1999). Such descriptions are quite consistent with the situation in the G-TEC program. Participants exchanged knowledge from different motivations and disciplines within a temporary project of cross-boundary coordination. Thus, we set the trading zone as a framework for entrepreneurship education through university–industry collaboration.

With the help of the trading zone metaphor, we can indicate that the exchange happens when project teams have heterogeneous skills and mindsets. As our statistical examination and case description showed, students learned business skills and external partnership skills that they did not have previously, but were already possessed by the practitioners before the program started. Similarly, practitioner participants learned basic theory about technological development and commercialization that the students and faculty had had but the industry participants did not. Considering those results, we can say that trading happens because the two groups have different assets to offer. Thus, our next proposition is as follows:

> ***Proposition 2:*** The exchange of knowledge in education for technological entrepreneurship through university–industry collaboration is derived from the heterogeneity of practitioners and students.

Next, we analyze the consequences of that "trade." As past studies have shown, a trade does not mean a simple transfer of knowledge. Rather, it brings significant restructuring of each participant's body of knowledge through the combination of new and existing knowledge (Galison, 1997; Kellogg et al., 2006). Kellogg, Orlikowski, and Yates (2006) indicated from their analysis of cross-boundary coordination in a marketing project that the exchange between members brought ongoing revision of the work and their understandings. Our observation is in accordance with their findings: both students and practitioners refined their understanding of technology commercialization and what aspects should be considered important. Such restructuring of the body of knowledge would be the central contribution of education for entrepreneurship education through university–industry collaboration. It was not the simple collection of participants' skills and knowledge, but the integration of them, which leads to our next proposition:

> ***Proposition 3:*** Participants of education for technological entrepreneurship through university–industry collaboration restructure their body of knowledge through their interactions with participants from different organizations.

The role of the faculty and facilitation staff should also be considered when attempting to understand the mechanism of this trading zone. In our observations, faculty members provided access to a body of knowledge about technology commercialization, and facilitators provided an introduction to the group project. Both of them encouraged teams to communicate effectively to find a solution, and they committed the participants to that problem-solving effort. From the viewpoint of a trading zone, the role of program facilitators could be a mediator or an agent of the exchange. They usually kept silent as long as the interactions between participants were proceeding smoothly. However, when needed, the program facilitators were able to intervene to get the teams back on track. Furthermore, introductory instruction by the facilitators provided the shared language used in the projects, which made it easier for participants to understand each other's ideas and opinions. Based on this interpretation of our results, we offer the following propositions about the role of facilitators:

> ***Proposition 4a:*** The faculty of an education program for technological entrepreneurship through university–industry collaboration provide fundamental knowledge to both practitioners and university students.

> ***Proposition 4b:*** Facilitators of an education for technological entrepreneurship through university–industry collaboration work as mediators in the exchange of knowledge.

Finally, we consider the effect of the temporary nature of the education program. In our observations, participants showed high motivation for the project work and were stimulated by the unique situation. Student participants felt that the G-TEC program was a special occasion, because it gave them the chance to meet skillful practitioners, to show their ability in technology commercialization, and to find an opportunity for venturing. Similarly, practitioner participants saw the G-TEC program as a precious opportunity to study at university again, to meet highly educated students and professors, and to try new things that could not be permitted within their companies. The G-TEC program worked as a "trading zone" that was a special place for knowledge exchange. It was independent from the participants' ordinary jobs or studies, thus they were allowed to undertake bold challenges without risk, and they felt more motivated than usual. The extraordinary and temporary nature of the program heightened the learning performance of the participants, and leads us to the following proposition:

> ***Proposition 5:*** An extraordinary and temporary context can activate participant learning in education through university–industry collaboration.

In Figure 1, we summarize our findings into one picture that describes the overall model of education through university–industry collaboration from the viewpoint of the trading zone metaphor. The G-TEC program is a temporary, extraordinary context that facilitates interactions between practitioners and students. Student-side participants and industry-side participants exchange assets with each other: students brought academic theory and framework, innocent and unbiased viewpoints, and the academic mindset. Practitioners brought practical know-how, realistic views of business, and a challenging spirit for commercialization. The heterogeneity among participants became the basis for knowledge exchange, while program lecturers and staff established a shared language to facilitate the interaction. This trading zone can be proposed as a potential framework for technology entrepreneurship education through university–industry collaboration.

Conclusion

As reviewed above, there are few studies about university–industry collaboration for education, despite the attention being paid to university–industry collaboration in general (Perkmann & Walsh, 2007). Based on a case description and analysis of the G-TEC program at Osaka University in Japan, we introduced the trading zone (Galison, 1997; Vaughan, 1999) as a potential framework for the exchange of knowledge between groups. It provides a viewpoint that, in a cross-border project, the exchange of knowledge happens between heterogeneous members under the extraordinary and temporary conditions. Each member transacts with their own interests, and the result is improved knowledge for every participant. We believe our work can form a basis for analyzing and discussing this style of education through university–industry collaboration.

Our findings have practical implications for the designers or managers of entrepreneurship education programs. Our analysis indicates that diversity among participants is critical to the education performance of the G-TEC program. Program staff should mediate and facilitate the interaction with those diverse participants, and the program should nurture a feeling of freedom and an appreciation for its extraordinary context.

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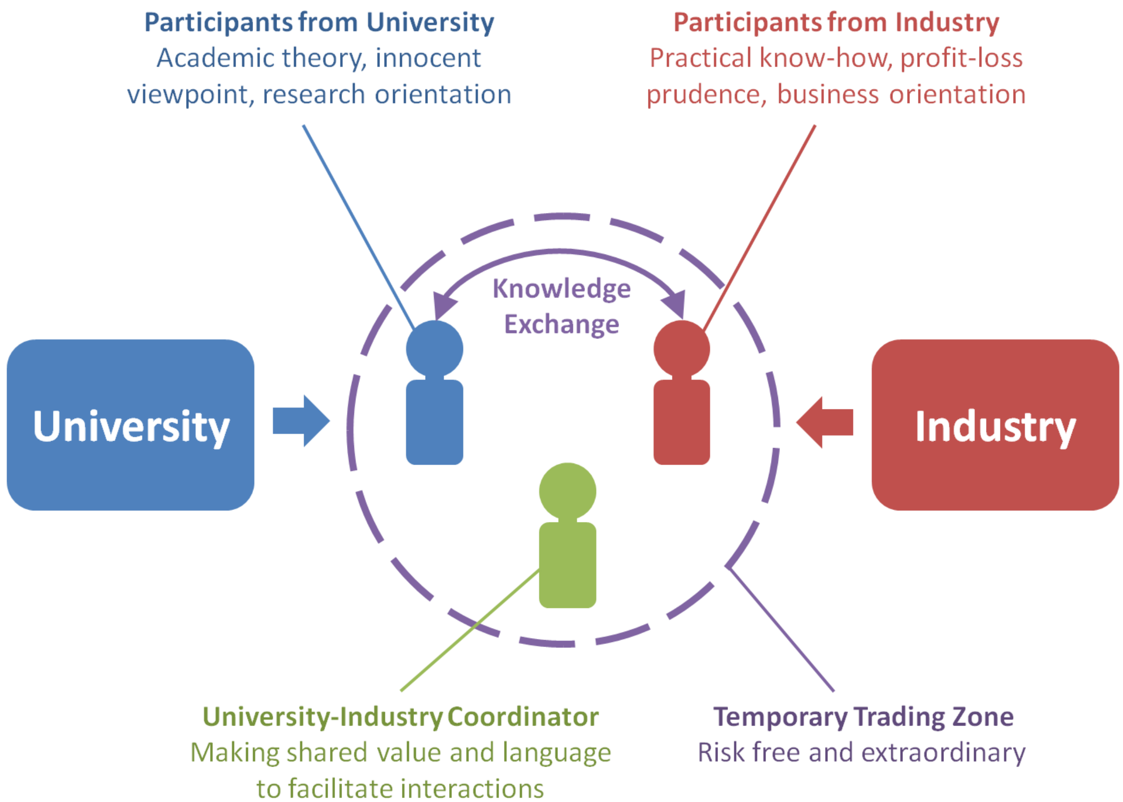

Figure 1. The "trading zone" framework: technology entrepreneurship education through university–industry collaboration

However, our findings are limited in the extent to which they can be generalized. The applicability of our findings must be constrained in terms of external validity, given that this study is based on single case analysis. Ideas from the G-TEC program and the trading zone metaphor should be examined in future studies and with more samples. However, our findings do have some scope for generalizations given that our research site and the G-TEC program has typical settings of education through university–industry collaboration, and the trading zone analogy is in line with past studies (e.g., Cyert & Goodman, 1997; Dooley & Kirk, 2007). Thus, we have offered several general propositions that might have generality. Although it must be tested in future research, the viewpoint of a trading zone for university–industry collaboration may benefit the progress of the study of entrepreneurship education.

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TIM Lecture Series

Building Trust in an IoT-Enabled World

Jeremy Watson, John Marshall, Mike Young, Peter Smetny, and David Mann

> *"New technologies create wonderfully innovative products, but also create new vulnerabilities and new means of attack. Increasingly, the attacks are network-borne, targeting software and stored information through hacking, malware, or denial-of-service attacks. To address these vulnerabilities, we need to develop systems and software with fewer vulnerabilities and greater resistance. Certainly, trying to bolt on security to existing systems is recognized as not being terribly effective. We need to take a systems view."*
>
> Jeremy Watson
> President of the Institution of Engineering and Technology (IET)

Overview

The Internet of Things (IoT) covers a wide spectrum of human endeavour, and there are great concerns about the safety, security, and robustness of systems and networks that will enable this massive connected environment. To share insights about the increasingly important topic of trust and security in the IoT, the first TIM lecture of 2017 was jointly organized by the IET Ottawa Local Network and Carleton University's TIM Program (timprogram.ca) in Ottawa, Canada.

David Mann, Director and Chief Security Officer at in-Bay Technologies (https://inbaytech.com/) and Chairman of the IET Ottawa Local Network introduced the four presentations, each of which offered a different perspective on building trust in an IoT-enabled world:

1. IET Initiatives in Cybersecurity and the IoT
   (Jeremy Watson – IET)

2. Trust as a Service
   (John Marshall – InBay Technologies)

3. Wireless Security in the IoT
   (Mike Young – Bastille)

4. WannaCry Ransomware and IoT Security
   (Peter Smetny – Fortinet)

The event was held at Carleton University on May 30th, 2017, where it was hosted by the Technology Innovation Management program as part of the TIM Lecture Series. TIM lectures provide a forum to promote the transfer of knowledge from university research to technology company executives and entrepreneurs as well as research and development personnel.

1. IET Initiatives in Cybersecurity and the IoT

Speaker: Jeremy Watson CBE, President, Institution of Engineering and Technology (IET; theiet.org)

Jeremy Watson introduced the IET's vision and mission, including the scope and nature of the organization's influence throughout the world. With over 167,000 members in 150 countries, the IET takes a multidisciplinary approach in all of its initiatives, which include:

- Informing the public and the wider engineering community.

- Offering professional registration and career development to IET members.

- Providing professional advice to governmental bodies, including calling on the UK government to make cybersecurity a priority.

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- Providing trusted e-learning for engineers at all career levels through the IET Academy (www.theiet.org/resources/academy/).

- Bringing science, technology, engineering, and mathematics to life in schools through the IET Faraday Program of educational resources, challenges, and events (faraday.theiet.org).

In setting the scene for the IET's initiatives in relation to cybersecurity and the IoT, Watson outlined the diverse and pervasive applications of the IoT in households (e.g., smart thermostats, white goods, televisions), building management systems (e.g., sensors and access controls, heating and cooling systems), industrial and utilities control systems (e.g., sensors and actuators), medical and hospital equipment (e.g., patient monitors and patient information recording), transport (e.g., condition monitoring and asset location), and retail. All of these areas will be affected by the IoT, which highlights the vital role of cybersecurity in the IoT, particularly with respect to the following risks:

- Information theft of personal data or patterns relating to building occupancy and utilization.

- Perturbation of operations, such as hacking into control networks to perturb asset operation. The denial of a physical service could occur, for example, by shutting down an air conditioner in a server room.

- Corruption of falsification of sensor data, for example, by spoofing a building management system or stealing energy by hacking smart meters.

- Falsification of information leading to supply chain or product provenance issues.

Next, Watson introduced the PETRAS Hub (petrashub.org), a research hub for cybersecurity and the Internet of Things, and for which he is Director and Principal Investigator. PETRAS brings together nine world-leading universities and dozens of international partners to collaborate on inter- and multi-disciplinary projects based on the following principles:

- Use an integrated approach of collaborative social and physical science expertise.

- Remove barriers to the beneficial adoption of IoT.

- Address generic knowledge gaps through case study approaches covering major sectors.

- Use innovative methodologies including "in the wild" and citizen science.

- Engage users by defining research agendas, participation in research, and matched funding.

For further reading on this topic, please see:

- *Code of Practice for Cybersecurity in the Built Environment*
  tinyurl.com/ycc2osxh

- *Engineering Secure Internet of Things Systems*
  dx.doi.org/10.1049/PBSE002E

- *The Internet of Things: Making the Most of the Second Digital Revolution* (The Blackett Review)
  tinyurl.com/plqn3xk

- PETRAS Hub
  petrashub.org

2. Trust as a Service

Speaker: John Marshall, Principal Software Engineer, inBay Technologies (inbaytech.com)

The second speaker, John Marshall, introduced the idQ Trust as a Service offering by inBay Technologies, which is designed to help overcome a lingering problem that takes on heightened importance with the IoT: identity assurance. Unsecured networks and weak passwords are commonplace, and the increasing frequency of data breaches means that the risk of compromised credentials is high and widespread. Marshall argued that a root cause is the underlying paradigm of the password model: a password is a secret, but that secret is not as safe as most people tend to think. Passwords are typically transmitted across networks, stored by service providers, reused for multiple services, easily forgotten, and may not even be secret at all (e.g., default passwords). Also, attackers can use dictionary attacks and brute force approaches mean that a password can be discovered in minutes or hours.

Instead, inBay Technologies proposes a paradigm shift: we should stop transmitting secrets across the network, we should stop sharing secrets with service providers, and we should adopt a strong authentication model. Using this new paradigm, idQ Trust as a Service uses a Trust-Relationship Code, which consists of a hardware component (chip/trusted platform module), a service component (provisioned by the service provider), and a personal component (runtime information from the user). The user and their mobile device *trust* each other based on a local authentication factor, such as a PIN or a fingerprint, which is only used at run-time and is not stored on the mobile device nor is it shared with service providers. Instead of transmitting usernames and passwords to the service providers, idQ uses algorithm-based network authentication. Based on digital signatures, a challenge is triggered that can only be answered by a trusted user–device pairing. There is no propagation of users secrets or attributes across the network.

Marshall next showed examples of how this new paradigm can be applied to the IoT in the future: by enabling user-to-device authentication (e.g., for devices in the field) and device-to-device authentication, to protect data repositories, and for authorizing updates and provisioning. inBay Technologies is currently exploring these applications to better secure the IoT through the idQ Trust as a Service approach.

3. Wireless Security in the IoT

Speaker: Mike Young, Senior Wireless Security Engineer, Bastille (bastille.net)

Bastille describes itself as providing "security for the Internet of Radios", because the security vulnerabilities in the IoT have less to do with the "things" themselves than the radios embedded within them. Equally, Bastille recognizes that most enterprises think of "wireless" as equivalent to "Wi-Fi" without considering (or monitoring) the vast number of other protocols operating invisibly in their airspace.

As Mike Young described, companies spend substantial time and money securing the perimeter of their networks with firewalls, intrusion detection, exfiltration detection, etc. while often ignoring the many gigabytes of data leaving the premises via radio signals, for example through company phones, personal phones, hotspots, rogue cell towers, radio-ready infrastructure, GSM listening and surveillance devices, and IoT devices. Indeed, "covert wireless" devices are already infiltrating enterprises today, and many seemingly mundane devices are vulnerable as entry points, even including wireless mice and keyboards.

Bastille's wireless and IoT scanning and malware prevention systems are designed to help enterprise security teams to assess and mitigate the risk associated with the growing "Internet of Radios". Bastille's software and security sensors "bring visibility to devices emitting radio signals (Wi-Fi, cellular, wireless dongles, and other IoT communications) in an organization's airspace. The technology scans the entire radio spectrum, identifying devices on frequencies from 60 MHz to 6 GHz. This data is then gathered and stored, and mapped so that users can understand what devices are transmitting data, and from where in corporate airspace. This provides improved situational awareness of potential cyber threats and post-event forensic analysis."

4. WannaCry Ransomware and IoT Security

Speaker: Peter Smetny, Systems Engineering Director, Fortinet (fortinet.com)

Peter Smetny first discussed the recent WannaCry ransomware attack (wikipedia.org/wiki/WannaCry_ransomware_attack), which infected hundreds of thousands of computers within a single day: May 12, 2017. The ransomware targeted Windows-based systems, encrypting a user's data and demanding a ransom to be paid in Bitcoin. WannaCry spread with a worm-like mechanism that scanned for vulnerable systems then gained backdoor access using code leaked from the United States National Security Agency (NSA) to target vulnerable systems from Windows XP to Windows 10 then install and execute a copy of itself. The particularly unique aspects were the worm behaviour, the vulnerability of systems that had not been updated despite the availability of effective patches, and the user of leaked NSA exploits within the ransomware.

The infection spread to over 150 countries and more than 230,000 systems. Many industries were affected, although key among them were healthcare and education, because these industries often run legacy software and may be slow to apply updates to their systems. However, the attack ultimately was not as damaging to users or as lucrative for the attackers as it might have been. Fortunately, a security researcher, Marcus Hitchens, discovered and closed a "kill switch" capability within the worm that dramatically slowed further propagation of the ransomware. Soon, most systems had been updated and were no longer vulnerable, although variants of the ransomware (without the kill switch) also appeared quickly.

Smetny then offered short- and long-term recommendations for protection and recovery from similar attacks. In the short-term, he encouraged individuals and organizations to:

1. Patch systems and review patching processes.

2. Test backups.

3. Reinstall operating systems, preferably a proper reinstallation and not a restore process.

4. Regularly run a full anti-virus scan of all systems.

5. Disable Windows' Server Message Block (SMB) if not used.

6. Periodically run a vulnerability scan.

Over the mid-to-long term organizations should:

1. Establish a Next-Generation Firewall (NGFW) Perimeter.

2. Set up an Internal Segmentation Firewall (ISFW).

3. Implement Security Information and Event Management (SIEM) for threat hunting via hashes and to monitor infection spread.

4. Recognize the need for sandboxing for zero-day attacks.

5. Evaluate their protection strategy.

6. Include a self-audit capability on the Next-Generation Firewall.

7. Make full use of threat intelligence.

Smetny concluded the lecture by describing Fortinet's Security Fabric, which is designed to cover an organization's entire attack surface to reduce risk and increase visibility and operational efficiency, and FortiGuard, a comprehensive suite of antivirus, antispyware, intrusion protection, and web content filtering capabilities that draws upon global intelligence and threat sharing. To address the complexities of the IoT, Fortinet adds capabilities around "learning" and "managing", which help organizations to not only identify but also categorize and protect the devices in their environment. These capabilities enable organizations to quickly make a determination about whether an IoT device should be trusted or untrusted, define what segments of the network it should be allowed to access or can access it, and further lock down segments and communications to industrial IoT with new protocol and application controls. Thus, organizations can leverage the IoT as a business enabler while protecting such devices (and the organization from them), even when the devices are not inherently secure.

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About the Speakers

Jeremy Watson CBE is President and Fellow of the IET and Professor of Engineering Systems and Vice-Dean (Mission) in the Faculty of Engineering Sciences, based in the Department of Science Technology, Engineering and Public Policy at University College London. He is also Chief Scientist and Engineer at the Building Research Establishment (BRE). Until November 2012, Jeremy was Chief Scientific Advisor for the Department of Communities & Local Government (DCLG). He worked as Arup's Global Research Director between 2006 and 2013. Jeremy was awarded a CBE in the Queen's 2013 Birthday honours for services to engineering. An engineer by training, Jeremy has experience as a practitioner and director of pure and applied research and development in industry, the public sector, and academia. He has held research and technical management roles in industry and universities plus voluntary service with the DTI and BIS. His interests include interactions in, and the design of, socio-technical systems, emerging technology identification, development and deployment, and strategic innovation processes. Jeremy is a Chartered Engineer, a Fellow of the Royal Academy of Engineering, a Fellow of the Institution of Civil Engineers. He is a former Board member of the UK Government Technology Strategy Board (Innovate UK), and he is a founding trustee and Chair-elect of the Institute for Sustainability. He chairs the Natural Environment Research Council (NERC) Innovation Advisory Board and BuildingSMART UK, and until recently, served on the Council of the Engineering & Physical Sciences Research Council (EPSRC).

John Marshall is Principal Software Engineer at inBay Technologies in Kanata, Canada. He has over 20 years of experience as a software architect and technical leader developing real-time embedded telecommunications software, with a passion for improving software development. Previously, he worked as a Senior Software Engineer at Avaya and Software Architect for Nortel Networks. He holds a Bachelor's degrees in Computing Science from the Technical University of Nova Scotia in Halifax, Canada, and in Mathematics from Dalhousie University, also in Halifax.

Mike Young is a Senior Wireless Security Engineer at Bastille in New York, United States. He founded the Connecticut ISSA chapter and is currently a board member of the New York Metro ISSA. He has worked at Verizon, Verisign, RSA Security, and many security startups. He gave a speech on "Applying PKI" at the NSA in Fort Meade, Maryland. Mike received his Bachelor's degree in IT Management from Fordham University in New York, and he holds a Master's degree in IT Management from the University of Virginia in Charlottesville.

Peter Smetny is the Systems Engineering Director at Fortinet in Ottawa, Canada. As a technical architect, Peter has extensive experience in systems infrastructure design and implementation. He offers vast experience as a network/security architect, with a wide range of network devices, protocols, applications, operating systems, as well as integration, best practice, and design knowledge. His success is attributed to a demonstrated sense of accomplishment, leadership, dedication and initiative. Peter holds a Bachelor of Engineering degree from Carleton University in Ottawa, Canada.

David Mann is Director and Chief Security Officer of inBay Technologies in Kanata, Canada. He is a visionary innovator and calculated risk-taker with expertise in creating and leading new business ventures. He is a former Nortel executive, where amongst many achievements he nurtured the development of Entrust, a pioneer digital security company, leading to its $700+ million IPO. David actively engages in executive mentoring and advising Canada's leading researchers in the futures of cybersecurity, web network evolution, and the rapidly changing market of smart web-based applications. David is the Chair of several not-for-profit organizations, including the IET Ottawa Local Network, and he is an honorary member of the Canadian Association for the Advancement of Science.

This report was written by Chris McPhee.

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Keywords: cybersecurity, Internet of Things, IoT, trust, wireless, WannaCry, ransomware

Author Guidelines

These guidelines should assist in the process of translating your expertise into a focused article that adds to the knowledge resources available through the *Technology Innovation Management Review*. Prior to writing an article, we recommend that you contact the Editor to discuss your article topic, the author guidelines, upcoming editorial themes, and the submission process: timreview.ca/contact

Topic

Start by asking yourself:

- Does my research or experience provide any new insights or perspectives?

- Do I often find myself having to explain this topic when I meet people as they are unaware of its relevance?

- Do I believe that I could have saved myself time, money, and frustration if someone had explained to me the issues surrounding this topic?

- Am I constantly correcting misconceptions regarding this topic?

- Am I considered to be an expert in this field? For example, do I present my research or experience at conferences?

If your answer is "yes" to any of these questions, your topic is likely of interest to readers of the TIM Review.

When writing your article, keep the following points in mind:

- Emphasize the practical application of your insights or research.

- Thoroughly examine the topic; don't leave the reader wishing for more.

- Know your central theme and stick to it.

- Demonstrate your depth of understanding for the topic, and that you have considered its benefits, possible outcomes, and applicability.

- Write in a formal, analytical style. Third-person voice is recommended; first-person voice may also be acceptable depending on the perspective of your article.

Format

1. Use an article template: .doc .odt

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6. Provide a 2-3 paragraph conclusion that summarizes the article's main points and leaves the reader with the most important messages.

7. Include a 75-150 word biography.

8. List the references at the end of the article.

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