Interdisciplinary Cooperation Management in Research Clusters: A Review of Twelve Years

Sarah Müller-Abdelrazeq[1], Philipp Brauner[2], André Calero-Valdez[2], Ulrich Jansen[3], Laura Platte[1], Anne Kathrin Schaar[2], Linda Steuer[2], Sebastian Zachow[1], Kathrin Schönefeld[1], Max Haberstroh[1], Carmen Leicht-Scholten[2], Martina Ziefle[2] and Ingrid Isenhardt[1]
[1]Institute of Information Management in Mechanical Engineering (IMA), Aachen, Germany
[2]Human-Computer Interaction Center (HCIC), Aachen, Germany
[3]Nonlinear Dynamics of Laser Manufacturing Processes Instruction and Research Department (NLD), Aachen, Germany
[4]Gender and Diversity in Engineering (GDI), Aachen, Germany
sarah.mueller@ima-ifu.rwth-aachen.de
brauner@comm.rwth-aachen.de
calero-valdez@comm.rwth-aachen.de
ulrich.jansen@ilt.fraunhofer.de
laura.platte@ima-ifu.rwth-aachen.de
schaar@comm.rwth-aachen.de
linda.steuer@gdi.rwth-aachen.de
sebastian.zachow@ima-ifu.rwth-aachen.de
kathrin.schoenefeld@ima-ifu.rwth-aachen.de
max.haberstroh@ima-ifu.rwth-aachen.de
carmen.leicht@gdi.rwth-aachen.de
ziefle@comm.rwth-aachen.de
ingrid.isenhardt@ima-ifu.rwth-aachen.de

Abstract: As an interdisciplinary research network, the Cluster of Excellence "Integrative Production Technology for High-Wage Countries" (CoE) comprises of around 150 researchers. Their scientific background ranges from mechanical engineering and computer science to social sciences such as sociology and psychology. In addition to content- and method-based challenges, the CoE's employees are faced with heterogenic organizational cultures, different hierarchical levels, an imbalanced gender distribution, and a high employee fluctuation. The sub-project Scientific Cooperation Engineering 1 (CSP1) addresses the challenge of interdisciplinary cooperation and organizational learning and aims at fostering interdisciplinarity and its synergies as a source of innovation. Therefore, the project examines means of reaching an organizational development, ranging from temporal structures to a sustainable network in production technology. To achieve this aim, a broad range of means has been developed during the last twelve years: In addition to physical measures such as regular network events and trainings, virtual measures such as the Terminology App were focused. The app is an algorithmic analysis method for uncovering latent topic structures of publications of the CoE to highlight thematic intersections and synergy potentials. The detection and promotion of has been a vital and long known element in knowledge management. Furthermore, CSP1 focusses on project management and thus developed evaluation tools to measure and control the success of interdisciplinary cooperation. In addition to the cooperation fostering measures, CSP1 conducted studies about interdisciplinarity and diversity and their relationship with innovation. The scientific background of these means and the research results of CSP1 are outlined in this paper to offer approaches for successful interdisciplinary cooperation management.

Keywords: Interdisciplinary Cooperation, Interdisciplinarity, Cluster of Excellence, Research Organization, Human Resource Management

1. Introduction

The major challenges facing our society cannot be handled by one discipline alone (Sung et al., 2003), but rather by connecting traditional disciplines. In recent decades, there has been an increase in interdisciplinary cooperation in both research and business (Lattuca et al., 2011). National and international research funding aims for interdisciplinarity to promote innovation and progress through interdisciplinary projects (DFG, 2013).

Interdisciplinarity requires a close integration of disciplines to generate new perspectives and solutions. Bergmann and Schramm (2008) state that not only integration on a cognitive, but also on a social, communicative, organizational, and possibly technical level leads to the capability of interdisciplinary research to achieve good results.

Interdisciplinary cooperation is described as a particularly challenging experience by the people involved; the professional exchange of expertise with people from different disciplines requires intensive reflection of one's own socialization and one's own disciplinary abilities (Dahlin et al., 2005). Thus, such kind of cooperation is more likely to be a source of conflict (Jehn et al., 1999), verified by the fact that a significant number of interdisciplinary research projects are not as successful as hoped (Rogers et al., 2005).

In order to be able to understand, promote, and steer the interdisciplinary cooperation within the *Cluster of Excellence* (CoE) "Integrative Production Technology for High-Wage Countries", the project *Cross Sectional Processes* 1 "Scientific Cooperation Engineering" (CSP1) was created. Within the CoE, around 150 scientists of different disciplines are working on the development of sustainable solutions for production in the future. Since the beginning of the CoE in 2006, CSP1 is an integral part of it. CSP1 is divided in four fields of action, with every field including several measures and/or studies (see **Error! Reference source not found.**):

- *Performance Measurement* deals with evaluation and control of interdisciplinary cooperation.
- *Diversity Management* studies and promotes diversity.
- *Knowledge and Cooperation Engineering* develops instruments for acquisition, transmission and control of interdisciplinary knowledge.
- *Interdisciplinary Innovation Management* analyses and visualizes scientific output processes.

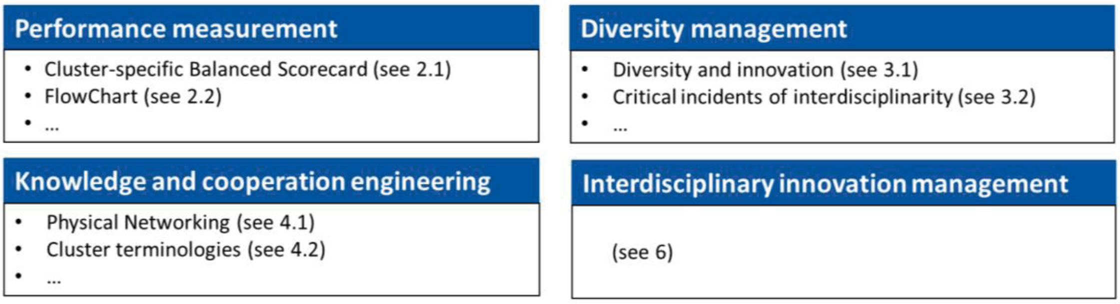

Figure 1: Overview of the fields of action and exemplary measures.

This paper gives insights into the manifold methods and studies within these fields of action of the past twelve years and offers an approach to measure the success of promoting interdisciplinary cooperation.

2. Performance measurement

Within this field of action, tools have been adapted in order to derive insights from the process performance of the CoE on all hierarchical levels. Furthermore, project management and planning processes are supported. Two remarkable measures, which serve as an example for this field of action, are the *cluster-specific Balanced Scorecard* and the *FlowChart*.

2.1 Cluster-specific Balanced Scorecard

To facilitate organizational learning regarding the interdisciplinary cooperation and its management, a continuous regulatory process has been implemented in the CoE. Through an iterative loop of data collection, data analysis and adjustment of measures, the scientific performance has been systematically monitored, controlled and shaped (Welter et al., 2011). The Balanced Scorecard (BSC)-based evaluation has been conducted at the end of every year since 2007, collecting quantitative and qualitative data on different aspects of the work and collaboration within the CoE. The BSC for the CoE was originally based on the BSC developed by Kaplan and Norton (1992), a controlling instrument that offers the management of an organization insights into different non-monetary aspects of its performance. The cluster-specific BSC was adapted to fit the informational needs of the cluster management including four perspectives that influence one another: an *internal perspective* focusing on research cooperation, a *perspective on learning and development*, an *output* or *client perspective* and a *financial perspective* (Welter, 2013). All perspectives were operationalized in a web-based questionnaire.

The data of the evaluation have been analyzed and interpreted both in cross-section for each year as well as in the form of a time series of the annual arithmetic mean. Results of the evaluation have been made available to all members of the cluster. In addition, a management workshop takes up the results of the survey to systematically strengthen the positive trends and address the identified challenges of the scientific cooperation. Needs for action and possible measures are consequently derived, for example the introduction of a newsletter to address a perceived lack in the distribution of project results (see Figure 2, left diagram).

The evaluation results have shown a positive trend in the appraisal of, for example, the measures *usefulness of scientific cooperation* and the *quality of scientific* (see Figure 2, right diagram).

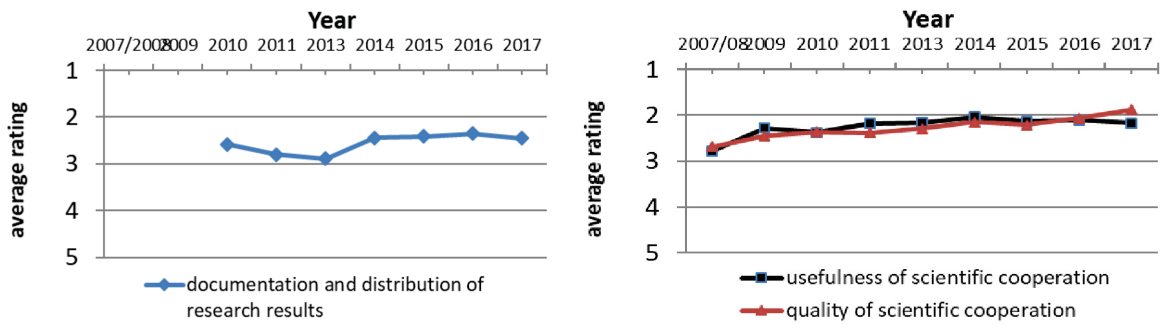

Figure 2: Exemplary time series of items of the cluster-specific BSC (Likert-scale 1 (good) to 5 (bad), $49 < n < 121$).

2.2 FlowChart

Clear communication and a common understanding about the research process are crucial elements in research collaborations with multiple partners involved. To support this process, a web-based research planning tool was developed and tested (Jansen and Schulz, 2015). Project planning and managing tools of different complexity exist, however these tools suffer from poor usage in research projects. Literature review on so-called project management information systems led to key features for project planning systems (Jaafari and Manivong, 1998). Additional requirements analysis led to a lightweight and easy-to-use standardized project planning form that has been implemented as a centralized web-based tool. To meet the requirements, a pictorial representation of the research plan has been derived in a flow-chart-like approach, resulting in the so-called *FlowChart*. This tool displays a single screen view of the initial situation, the research plan and project objectives as an interactive web application (Vaegs et al., 2014). Additionally, it provides the essential amount of information about the current project state for all members of the project team in an intuitively understandable manner. The clear aggregation of all relevant work packages and their contribution for the project goals is vital for decision making during the project. The tool also provides an indicator for the fulfilment level of the individual work packages and therefore offers project controlling and performance management capabilities. However, the more important advantage of this feature is the detection of dependency conflicts, if any work packages are delayed or even cannot be fulfilled.

At the end of 2016, the tool has been rolled out and a small usage study of the tool was carried out in the developing department. Furthermore, enhancements of the concepts were derived from interviews (Jansen and Schulz, 2017), including relation management between different work packages inside a research project to reflect work package dependencies, resource management to detect resource conflicts between multiple projects and notification of changes in the research plan. These enhancements are currently included into the *FlowChart*, so that the finalized tool will provide project-planning capabilities that are tailored to the scientific research environment.

3. Diversity management

To create an environment where different experiences and skills are valued as a crucial part of an innovation, the *Diversity Management* aims to increase gender, cultural and disciplinary diversity within the CoE. To find the right management approaches, it is critical to understand the diversity in the cluster. Two main studies of CSP1 are described in the following.

3.1 Diversity and innovation

Diverse teams increase the development of inventions and lead to more sustainable and socially responsible products and services (Leicht-Scholten, 2018). The success of a diverse team is not guaranteed, as increasing employee diversity correlates with the need for active exchange and coordination to avoid misunderstandings and conflicts (Díaz-García et al., 2014). To investigate the requirements and appropriate approaches for implementing a management approach that is tailored to the organization and the environment of the CoE, a research concept has been developed that allows a sustainable strategy development.

In a first step, the status of diversity within the CoE was assessed. Considering the CoE as a holistic organization, the quantitative evaluation of employee data shows a research alliance that is male-dominated, with 82.4% of all employees having their professional background in engineering faculties. 9.7% of the researchers have a non-German cultural background (Steuer et al., 2017).

In a following step, the project sought to analyze the potential of a diverse workforce (Sharma et al., 2017). A comparison group of three research organizations with differing workforce diversity was examined. The number of publications measured scientific success. Results show that the most diverse group in all aspects, being gender, age, culture, and discipline, is also the most successful group. The CoE represents the second most successful group although it only has limited gender and cultural diversity compared to the group that can be characterized by a mono-disciplinary and young workforce. However, it must be taken into consideration that scientific success cannot be completely attributed to the presence of specific diversity dimensions. After analyzing the status quo and the potential of diversity, existing management strategies and prevailing mind-sets in the context of diversity and innovation were object of investigation in the third phase. The intention was to develop a diversity and innovation management strategy that is tailored to the CoE, facilitates change processes and is tied to existing structures and measures. To reveal persisting attitudes and experiences, interviews were conducted within the CoE. The interviews lead to a category system consisting of seven categories with 28 sub-categories, in turn leading to the identification of six superordinated types of researchers: the Superficially Informed, the Active Follower, the Passive Follower, the Intentional Refuser, the Sceptic and the Reflected User (Steuer et al., 2017; Steuer and Leicht-Scholten, 2017).

Especially with regard to diversity management, the level of management plays a key role since managers function as role models for norms and values and thus corporate culture (Sackmann, 2004). As a result, reflection of the given situation is a crucial aspect while developing a tailored management concept.

3.2 Critical incidents of interdisciplinarity

In order to identify critical incidents (CI) for the success of the CoE, Jooß (2014) conducted a comprehensive long-term study. By using the Critical Incidents Technique (Flanagan, 1954), CIs (i.e. events that have had a particularly good or particularly bad effect) were extracted from the data. Based on empirical theories, the CIs were clustered in generalizable patterns hence providing action recommendations for the cluster management:

- I*ntegration and allocation of time* cumulated corresponding CIs. In order to ensure successful cooperation, integration of interdisciplinary knowledge and methods is critical. Therefore, constant communication between the stakeholders is crucial. The researchers need to be aware of existing competences of one another. Based on this awareness, the researchers should develop common language. It is also necessary to work out the interfaces and limits of involved disciplines and, at best, to learn from each other. This complex negotiation process requires time and organizational support since it does not emerge by itself. For this purpose, an explicit allocation of time is needed to foster constant exchange and should be provided by the organization to a sufficient extent. This process can be further supported by spatial proximity.
- I*ntegrated knowledge management regarding the common interdisciplinary vision* focuses on the importance of a common vision and continuous knowledge management with respect to realization of the vision for successful cooperation. A common vision is the basis for identification with and motivation for interdisciplinary cooperation. It needs to be defined, the researchers should be aware of it and its significance, and they should be able to illustrate their individual contribution to the overall goal. Concerning the vision, an enduring support for knowledge exchange should be given and regular networking activities should be fostered. This can be encouraged by the sub-project managers, who

act like key persons for networking. They can initiate exchanges about research findings that are crucial for further cooperation. For such exchanges, adequate temporal freedom is necessary.

- The third pattern accumulates CIs in the fields of *recursive and process-related support and participation of stakeholders*. Participation of involved actors as well as a recursive and process-accompanying support are of special importance in the CIs of this pattern.

Based on this exploratory groundwork, a questionnaire for examining the given CIs was developed (Müller et al., 2017). This primary questionnaire – as a first attempt for quantitatively measuring CIs of interdisciplinarity – enables a cost-effective evaluation and facilitates the support of cooperation.

4. Knowledge and cooperation engineering

Knowledge and Cooperation Engineering comprises the interaction of data, information and knowledge on all organizational levels to support a sustainable development of the CoE. This includes physical networking (workshops and training) as well as data-driven methods like the *Terminology App* to support communication and exchange as a foundation for further cooperation.

4.1 Physical networking

Physical networking processes, focusing on scholarly and interdisciplinary exchange, are especially requested by the members of the CoE. To meet this request, interventions like networking events are conducted. For example, interdisciplinary trainings serve not only as further training, but also as a platform of exchange.

Colloquia of employees are part of the networking strategy of the CoE since 2008 and aim at promoting cluster-internal cooperation as well as transfer of knowledge. They are designed as workshops with varying subjects. Results of the formative event evaluation are used to derive useful topics from the actor's perspective. The final concepts and topics are determined in close cooperation with the cluster management and CSP1.

Different developmental stages can be clustered within the topics and concepts of the colloquia. These stages show a strong association to the typical development phases of networks (Müller et al., 2015) and reflect the organizational learning processes within the CoE.

1. *Initiation:* The first colloquia aimed at creating a common purpose or rather a joint vision and mission of the line of research.
2. *Interfaces:* As a next step, highlighting interfaces between the various disciplines and projects became a major element of the colloquia. For improvement of interdisciplinary communication, synergies and ideas for new cooperation should be enhanced.
3. *Learning:* The third period of colloquia focused on interdisciplinary mutual learning. This was implemented by means of presentations in so-called micro-trainings. These are thought to support an enhanced knowledge transfer in an everyday work environment. The presentations convey information on the methods and contents of the diverse disciplines (e.g. rapid prototyping, digital twin vs. digital shadow).
4. *Sustainability:* The currently ongoing colloquia aim at developing visions for the future, despite the end of the funding period. Therefore, deduced synergies were evaluated to set up networking sessions on the project level. In the following step, these synergies were used to develop future topics for the CoE.

Taking the participants' perspective into account, a descriptive analysis of the evaluation over time gives some hints for the importance of these networking events. The mean evaluation increased continuously which can be interpreted as an ongoing acceptance of the colloquia as a measure for supporting cooperation.

4.2 Cluster terminologies

To support networking and communication between entities and therefore the knowledge management within the cluster, data mining methods have been utilized. To visualize interfaces and create a common understanding of scientific terminologies, the *Terminology App* has been successfully developed and implemented for the members of the CoE. The app is used to support the knowledge management within the CoE by displaying definitions of terminologies and showing interconnections between research projects (Thiele et al., 2015).

The underlying technological framework is based on the automatic processing of scientific publications produced within the CoE (Thiele et al., 2016; Thiele et al., 2017). The automatic processing takes five subsequent steps: First, text mining is used to transform the underlying data, consisting of scientific publications, in a machine-readable form. Scientific publications are then grouped by entity, e.g. a research project. Second, we include topic modelling using the Latent Dirichlet Allocation (Blei et al., 2003): Different groups of words form a topic based on their frequency. Words are also labelled and, if they belong to the group forming a topic, ranked regarding their importance for the topic (Thiele et al., 2017). The third step classifies topics and their interconnections with other entities. The algorithm is not only considering words, but also the importance of each word and their relative frequency is taken into account. This leads to the fourth step being a graph-based visualization that represents topics, words and project-teams (see Figure **3**3). As a fifth step, human interaction provides a mean for the cluster to further initialize and support cooperation and networking activities.

Through direct linking to the corresponding documents, the app supports the knowledge management within the CoE and gives direct access to the research paper of other projects. All terminologies that have been identified by the system can be complemented with long and short definitions. The linkage between entities of the graph displays the affiliation between terminology and identified research projects. Additional information of the entities provides names of authors and keywords. The setup of the provided information about important terminologies and corresponding projects in one tool is a crucial success factor for the interdisciplinary cooperation between the participating researchers. Through visibility of other research projects and their participants - an incentive for initialization of interdisciplinary research is given.

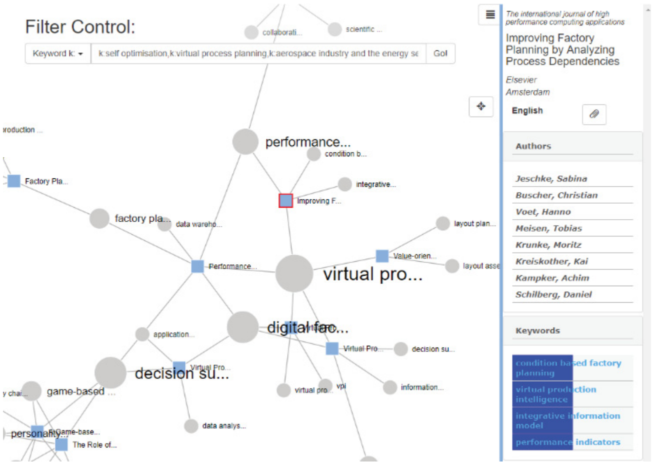

Figure 3: Visualization of the interface of the Terminology App, displaying terms interconnected to project (circles), scientific paper (squares), and corresponding authors.

5. Interdisciplinary innovation management

To foster the innovative potential, an interdisciplinary innovation management was established. First activities were focused on the understanding of perceived benefits and barriers of interdisciplinary work from the members point of view (Hamann et al., 2016). A mixed-method study revealed that barriers arise from communication problems, missing points of intersection as well as a lack of knowledge about the other disciplines' skills and topics (Hamann et al., 2016). Benefits are seen in the bundling and combination of knowledge from different disciplines and perspectives, which are perceived to promote innovative ideas and concepts. In addition, individual advantages on the part of the members, such as expansion of one's horizon could also be identified as benefits of interdisciplinary work (Hamann et al., 2016).

Based on these insights we focused on the derivation of suitable measures and methods for scientific investigation and support of interdisciplinary cooperation. As a measurable reference for scientific success, we have chosen academic publications. That is because publications are a broadly accepted criterion for measuring scientific impact. They are publicly available and their meta data indicate disciplinary and interdisciplinary collaborations (Garner et al., 2018). The corpus for our analysis contains over 1000 peer-reviewed articles published during the funding period of the CoE.

To use the publication data for both scientific analyses of cooperation and for supporting collaboration, an interactive visualization tool was developed and implemented into the cluster's social network platform (Calero Valdez et al., 2015; Calero Valdez et al., 2016; Schaar et al., 2013). The main goal of the tool was to enable self-reflection on publication efforts and output of individual members, workgroups, and the cluster. Workgroups and individuals were requested to use the tool to locate themselves and their influence on the cluster as a whole. Additionally, the tool should be a promoter for discovering new collaboration opportunities based on thematic proximity or strategic considerations (Calero Valdez et al., 2015).

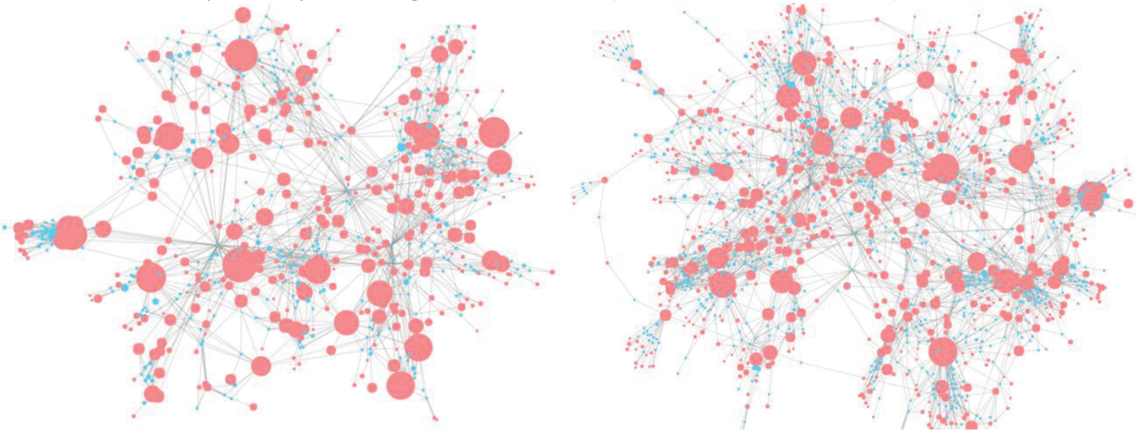

Figure 4: Publication graph from the first (2006-2011, left) and the second funding period (2012-2017, right). Red nodes are authors; blue nodes are publications. The size of the nodes depicts the amount of publications or co-authors depending on node type.

In parallel, we offered workshops on planning and writing disciplinary and interdisciplinary publications.

A bibliometric analysis showed that the number of publications currently still grows and the interconnectedness of the cluster increases (see Figure **4**4). Consequently, the CoE has shifted from rather isolated, disciplinary research towards more interdisciplinary collaboration. Identify missing links creates new opportunities for collaboration of heretofore non-connected researchers. Accompanying evaluations by the researchers and managers confirmed that a visualization of publication output enables them to reflect on their work and the cluster-specific structure (Calero Valdez et al., 2016; Schaar et al., 2013).

6. Discussion and outlook

Despite all challenges associated with interdisciplinary cooperation and the high fluctuation of researchers within the CoE, the BSC results show a constant, positive development for the indicators *quality of cooperation* and *use of cooperation*. This trend can be interpreted as a successful development of cooperation, which is promoted by the cluster management and various process-related networking activities of CSP1. Furthermore, the density of the publication graph shows that not only the quantity of publication increased with time, but especially the interconnectedness. This is a sign for the cross-project cooperation, which was significantly focused by the work in CSP1.

The measures of CSP1 focus on the operative level. Therefore, the transferability of most of the measures fostering cooperation towards another scientific or even industrial application is likely to be high. The cluster-specific BSC, for example, can be adapted, for instance, in order to support further surveys in an R&D context. As a follow-up, organizational design processes are supported with CSP1. The design and implementation of workshops aim at a reflection of the surveyed topics on various hierarchical levels. The *Terminology App*, as one of the virtual measures, could also be used to detect synergies between different departments, which are possibly unknown yet.

In addition to the ongoing measures (e.g. BSC), which will be continued, the transitional phase focuses in particular on the investigation and enhancement of innovative capability. Building on the previous work in text mining and topic recognition, further research with aim to understand how scientific topics evolve over time and how these insights can be used to strategically choose the research activities and cooperation in the cluster. To further strengthen the results from the CoE, interaction of humans, algorithms and machines must be investigated. Understanding how data influences visual representation and how visual representation shapes decision making is key to ensuring successful application of methods of artificial intelligence in production systems in industry 4.0. When production becomes truly smart and interconnected, it is critical to understand the impact of the human factor and the implications of different interfaces between human and artificial intelligence.

Acknowledgement

The authors would like to thank the German Research Foundation DFG for the kind support within the Cluster of Excellence "Integrative Production Technology for High-Wage Countries”.

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The Impact of Big Data on the South African Banking Industry

Kinyanjui Mungai and Amiena Bayat
University of the Western Cape, Cape Town, South Africa
3259032@myuwc.ac.za
amienabayat@gmail.com

Abstract: If finance enables production, technology in the financial services sector enhances the speed of accessing and transferring finances, ultimately facilitating more production. Accepting new technologies is therefore crucial to the success of any industry in the fourth industrial revolution. Technologies such as Social Media, Mobile, Analytics (and Big Data), Cloud, along with the Internet of Things (SMACT/SMACIT), have become pervasive digital disruptors which have fundamentally changed the business models and value propositions of firms across industries. The financial services sector has been disrupted by innovations such as M-Pesa, SnapScan and EcoCash, which have made it more inclusive. The growing smartphone uptake in South Africa and developing countries has removed barriers to financial services provision and has reduced barriers to information access. SMACT technologies offer an opportunity for the financial services sector to reduce the costs of banking in such a way that those who are underserved or unserved by the financial services sector are more informed and better able to access financial services through the removal of geographic barriers to banking and through the reduction of costs. Chigada and Hirschfelder (2017:3) state that the integration of the banking system is part of the critical functions of mobile banking. Lower-income classes, despite having individually weaker purchasing power, actually have astoundingly significant purchasing power at the collective level (Chigada & Hirschfelder, 2017:3). Mobile banking therefore seeks to integrate into the banking system this poor yet large population who collectively possess significant market power. In order to integrate the poor into the financial services sector, the benefits of mobile banking have to be conveyed to them in a way that clearly indicates simplicity and convenience (Ramavhona & Mokwena, 2010:5; Al-Jabri & Sohail, 2012:387; Ernst & Young, 2016:6). This paper aims to assess the digital disruption from big data of the South African financial services sector with a particular focus on financial inclusion. The study used a mixed method approach. For the qualitative method, data was collected from semi-structured interviews with key informants from the financial services sector and related fields of expertise.

Keywords: Big Data, Banking, Financial Sector, Digital Disruption

1. Introduction

The 2016-2017 Global Competitiveness Report by the World Economic Forum (WEF) ranks South Africa 47th globally in terms of competitiveness (Schwab, 2017:25). South Africa's ranking was attributed to the country being a frontrunner in the region in financial markets and infrastructure among other factors (Schwab, 2017:25). Moreover, South Africa ranked in the top five, out of 138 countries, for financial services meeting business needs, financing through local equity markets, soundness of banks and regulation of securities exchanges (Schwab, 2017:25). While the financial sector is thus a significant contributor to the South African real economy, the WEF notes that in order to increase competitiveness, there has to be a rise in productivity as well as a focus on creating an economic environment in which emerging business models and technologies can foster economic growth (Schwab, 2017:9).

The success of South Africa's financial sector is attributed to its meeting the needs of businesses and its efficient functionality in terms of providing finances without adversely affecting financial stability. An important factor impacting on the stability and profitability of banks is their ability to manage the information of their clients. The financial sector is heavily involved in information system management. Big data and analytics are key components of the back-office processes of financial services providers. Managing such information in a way that protects client information is crucial to the success of financial services providers and the continued existence of a financial service provider (FSP) in terms of not contravening the Protection of Personal Information (POPI) Act. The management and protection of data are particular forefront issues and so are opportunities for cloud computing. Cloud technology has been an important facilitator of innovation through the establishment of cloud platforms for innovators to develop applications. The banking industry, like any industry that has to warehouse large datasets, has had to make use of cloud computing in order to cut costs and increase the speed at which data can be retrieved.

It is well established that disadvantaged communities interact with formal banking channels less frequently due to socioeconomic barriers. One of the benefits of digital platforms is their ability to break socioeconomic barriers in terms of the costs of banking. The growing smartphone uptake in South Africa and other developing