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ARE YOU READY FOR DEVOPS? REQUIRED SKILL SET FOR DEVOPS TEAMS

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Research paper

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Abstract

In order to react quickly to changing environments and build a customer-centric setup, more and more organizations are deciding to work with the agile IT software development approach. But for the fast delivery of new software features in very short time, other parts of the IT department are necessary as well. Hence, the DevOps concept appears and connects development to IT operations activities within service-centric IT teams. To date, there has been very little empirical research on the skills required for the successful setup of a DevOps-oriented IT team. This study addresses this gap by conducting a multi-perspective research. We have collected data with the help of a workshop and interviews with IT experts. Seven skill categories—full-stack development, analysis, functional, decision-making, social, testing, and advisory skills—with 36 concrete skills were identified. Our study highlights that a combination of distinct development, operations, and management skills is necessary to successfully work within a DevOps team. This research explains core DevOps skill categories and provides a deeper understanding of the skill set of an ideal DevOps team setting. We describe these skills and skill categories and list their implications for research and practice.

Keywords: DevOps teams, skill set, concept of skills, agile software development, workshop, IT expert interviews

1 Introduction

Digital transformation has forced organizations to rethink their requirements for IT functions. The appearance of new digital technologies presents incumbent firms with changing opportunities on the one hand and major challenges on the other (Sebastian et al. 2017). These organizations have to think about how they can compete in the digital economy. Many old companies, which are at an early stage of digital transformation, are considering the capabilities necessary to develop themselves into digital leaders (Ross et al. 2016; Sebastian et al. 2017). IT organizations are under pressure to work with new technologies, improve their business understanding, enhance speed for delivering new products, and organize themselves to be more customer-centric (Bharadwaj et al. 2013). Consequently, more and more organizations are deciding to implement agile IT setups to foster innovative capabilities and agility (Lee et al. 2015).

To address the current challenges and enable future-proof IT setups, it is essential for IT organizations to implement agile IT teams (Cao et al. 2013). Further, digital transformation fosters the development of new capabilities within the IT function as well (Wiesche and Krcmar 2014). Agile software development is limited to the collaboration between business and software development (Lwakatare et al. 2016; Sebastian et al. 2017; Tripp et al. 2016). For the fast delivery of new software features and to enhance business value, agility has to be scaled to other parts of the IT function that are necessary for the service delivery lifecycle as well (Fitzgerald and Stol 2017; Matook et al. 2016; Ross et al. 2016). Hence, companies are transforming their IT units and implementing service-centric IT teams—the so-called DevOps teams (Sebastian et al. 2017). DevOps is an acronym of development and operation

(Lwakatare et al. 2016). DevOps combines the activities of software development and operations in one team and enables the continuous deployment of new features in short cycle times (Sebastian et al. 2017). Hence, response times for customer needs are drastically reduced through the better coordination of work (Lwakatare et al. 2016).

DevOps is a rising trend and is expected to become a competitive necessity. More and more IT organizations are deciding to implement the DevOps concept (Ross et al. 2016). According to a Gartner survey conducted in 2016, about 25% of 2,000 global IT companies will work with the DevOps concept and tools according to the DevOps toolchain (Rivera and van der Meulen 2015). Hence, DevOps is recognized as an important issue in the area of software development. Innovators in the digital area, like Amazon, have already adopted the DevOps approach and are now able to provide new codes to customers in seconds. It is clear that organizations have to develop DevOps capabilities to stay competitive through the delivery of rapid innovations (Sebastian et al. 2017). But the implementation of the DevOps concept entails extensive efforts by IT leaders to build and create new values by linking existing capabilities with novel ones (Ross et al. 2016). However, for many organizations, it is not clear which skills are needed to fulfil the different tasks that are expected from a DevOps team. Lack of skills in a project environments is one of the key factors for failure of IT projects (Keil et al. 2013; Pflügler et al. 2018). A distinct skill set is highly correlated with a successful project outcome (Napier et al. 2009); hence, it is necessary to understand the required skills of DevOps teams. Despite initial intentions to investigate forms of the DevOps concept (Lwakatare et al. 2016), there is very little empirical research on the skill set of successful DevOps teams. The goal of this study is to present an empirical skill set framework for DevOps teams. Hence, with this research, we wanted to answer the following research question: *What is the ideal skill set for successful DevOps teams?*

We conducted a case study with 10 participants as a pre-study and recognized that there is the need for a common framework about the key skill set that should be present within a DevOps team. This motivated us to set up a workshop with nine experienced IT consultants in the DevOps field, moderated by two researchers, to achieve deeper insights of the DevOps phenomenon. Subsequently, we conducted further interviews with IT consultants to verify our results. To this end, we have identified skill categories that describe the ideal DevOps team's skill set. The following sections of this paper explain the DevOps phenomenon and the concept of skills. Additionally, we focus on the presentation of the workshop findings and give a description of skill categories and their characteristics. Finally, we discuss our findings and conclude with implications for theory and practice.

2 Theoretical Background

2.1 DevOps teams

To handle the complexity of rapidly changing environments, IT organizations are deciding to implement product-oriented agile IT teams. The ability to adapt to new situations is a key requirement of high-performing software development teams (Burke et al. 2006). In changing environments, teams must be able to react fast and with precision. During the last few years, the use of agile software development methods has gained high popularity in a rising number of organizations (Tripp et al. 2016; West et al. 2010), primarily due to higher customer satisfaction ensured by the provided software as well as better software quality and higher project success (Maruping et al. 2009; Tripp et al. 2016). But research and practice highlight that a tighter collaboration between the development and the operations part of an IT function is necessary to ensure that errors are quickly fixed and the quality and resilience of the software are enhanced. DevOps can help to combine these approaches and reduce software cycles by pushing new code quickly into the production environment (Fitzgerald and Stol 2017). For the rapid delivery of new software features, innovations, quick handling of problems, and integrating maintenance activities, IT departments should use cross-functional teams rather than separated silo architectures (Fitzgerald and Stol 2014).

Prior research shows that agile software development is limited to the area of development activities. Therefore, in a lot of organizations, the agile approach does not go beyond development and customer-

gain deployments of new software features except in rare cases (Lwakatare et al. 2016). One reason for this is the poor communication and collaboration between developers and operations personnel. To address this issue, the DevOps approach enables the scaling of agility to the entire company (Gotel and Leip 2007). The aim of DevOps is to foster collaboration, automation, virtualization, and tools to bridge the activities of software development and operation (Humble and Molesky 2011; Lwakatare et al. 2016). Through DevOps, solutions are delivered to avoid interruptions between different stages of the complete software delivery process (Fitzgerald and Stol 2014). The entire software development life-cycle comprises the steps of planning, development, and operation tasks. DevOps helps companies to acquire the necessary speed and flexibility to ensure the constant and rapid development and implementation of digital innovation (Ross et al. 2016). Hence, risks associated with software releases can be reduced and feedback for new software features is received faster. In addition, agile methods can be used to manage the software development part and meetings of the team (Lwakatare et al. 2016).

From a practical point of view, the state of DevOps report shows that high-performing DevOps organizations are able to deploy 200 times more frequently than low-performers. The change failure rate is three times lower than in traditional settings. Further, DevOps teams spend 22% less time on unplanned work and rework and thus are able to spend more time on new feature development (Brown et al. 2016). Software development comprises the analysis of new requirement, design and coding activities, and verification and testing, whereas software operation focuses on maintenance and software installation tasks (Fitzgerald and Stol 2014). Within a DevOps team, a very broad understanding of skills is necessary. Whereas traditional silo-oriented IT functions foster specialized knowledge in one area, e.g. departments, DevOps teams need a very broad generalist setup over all tasks of the software delivery lifecycle for which they are responsible (Rouse 2016). Hence, in cross-functional IT teams, the same activities need to be implemented for service delivery as in traditional IT functions, with separated units of specialists.

2.2 Concept of skills

Skills or competency models are used to describe the abilities, knowledge, attitudes, and traits that are essential for the effective performance of an organizational position or role (Mansfield 1996; Matook and Maruping 2014). Usually, the term competency is used synonymously to skills, but there are fine differences. Skills denote the ability to finish tasks and solve problems through the application of knowledge, whereas competencies represent the ability to use skills, knowledge, and other personal or social capabilities to assess situations or to work in professional and personal environments (Boehm et al. 2013; Peppard 2010). Skills outline the abilities and behavior needed to competently perform activities and tasks that are expected by the DevOps team (Matook and Maruping 2014). Skill models are helpful for measuring the performance of people to find out if they need personal development or need to improve effectiveness. Furthermore, they support the recruitment and staff planning process (Lucia and Lepsinger 1999; Matook and Maruping 2014). Competencies are used in different research areas (Klendauer et al. 2012). A prominent example is the PMI's Project Competence Development framework, which states that project management competencies have three components—a personal, a performance, and a knowledge component (Institute 2002; Napier et al. 2009). Furthermore, prior literature describes skill requirements for IT project managers and fosters the understanding of the several skills that lead to successful project management. Napier et al. (2009) identify nine skill categories for IT project managers, including two skill categories that have rarely been discussed before. With regard to agile software development, Matook and Maruping (2014) present a competency model for customer representatives that was derived with the help of interviews. Ten competencies are presented and grouped within three core areas. However, we found little empirical evidence on the matter of skills needed by DevOps to perform successfully.

Skill models are used for different reasons, such as for the development of a job model or adapting existing skill models for similar job profiles. When starting from the scratch, deep knowledge, e.g. from experts, is necessary for generating suitable results (Matook and Maruping 2014). In DevOps

teams, little explanation of job roles exists; it is a concept for collaboration. Hence, the aim of this research is to focus on the general DevOps team's skill setup. A diverse skill set helps team members to develop new perspectives, ideas, and creative outcome (Lee and Xia 2010; Matook et al. 2016). There are two types of competencies—performance-based and attribute-based. Performance-based competencies focus on skillful practice. This type of competency depicts the job know-how of the individual (Crawford 2005; Napier et al. 2009). Competent DevOps team members can be identified with the help of effective actions that lead to successful outcome. Attribute-based competencies focus on skill-as-attributes, i.e. on the degree to which the individual has the necessary set of knowledge that a DevOps team should acquire. Attribute-based competencies are characterized by the know-what (Klendauer et al. 2012; Napier et al. 2009) of DevOps team members. Through skills-as-attributes perspectives, insights into requirements of DevOps teams for successful practice can be obtained.

The skillful-practice method addresses the behaviors, actions, and activities expected by the employers (Crawford 2005). This is helpful for the investigation of activities and interactions of effective project management. On the other hand, the skills-as-attribute method concentrates on explicit and necessary knowledge, skills, and personal characteristics (Napier et al. 2009) of DevOps team members. This method is helpful for investigating required skills based on contextual aspects, measuring the relationship between the skill set and outcome of projects. For practical purposes, it is helpful to understand which skills should be considered when a DevOps team is set up. These skills can be identified through different research methods, such as with the help of qualitative methods like expert interviews, as done in prior research (Klendauer et al. 2012; Napier et al. 2009).

From the perspective of agile development, literature does not deliver a broader mix of skills (Matook and Maruping 2014); hence, there is a need for skill models in the area of DevOps-oriented working. For the purpose of this research, we have chosen the skill-as-attribute perspective for investigating the DevOps team members' skills. We want to provide deep insights into the skill set of DevOps teams and consider skills as mandatory for the successful performance of a DevOps team.

3 Research Method

To answer our research question, we conducted a multi-perspective research approach (Boehm et al. 2013). Therefore, we decided to undertake a comprehensive multiple-case study among companies that are already working with the DevOps approach. The qualitative instrument of the multiple-case study with 10 cases can be seen as the pre-study, which delivers the basis for a workshop with IT experts of one IT consultancy company. Workshops are a good method to study new and arising phenomena, because they allow discussion about the answers of the participants in several rounds (Boehm et al. 2013). Afterwards, three interviews with IT consultants were conducted for verification. Hence, in this paper, we use the workshop method and subsequent interviews to identify and verify the key skill set of DevOps teams.

For the case study, we contacted different firms from different industries via email and telephone. Ultimately, 10 organization agreed to participate with one DevOps team in the case study. The case study approach is defined as "an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context" (Yin 2009, p. 18). Since the phenomenon of DevOps is quite new and unexplored (Yin 2009), the case study approach is appropriate. The advantage of case studies is that they can zoom in on real-life situations and test or develop theoretical perspectives in relation to certain phenomena as they unfold in practice (Flyvbjerg 2006). For doing so, we were able to investigate a row of skills and skill categories implemented within a DevOps team. An interview guideline not only helped to keep the interaction focused as data collection proceeded, it was also used to ensure comparability of the interview data across individuals, settings, and researchers (Maxwell 2013). Each interview lasted about 45–75 minutes and was mainly conducted through face-to-face meetings or by telephone. At least one manager (e.g. team lead) and a person concerned with daily business tasks were interviewed. Selecting both managers and team members enabled us to gain knowledge from a leadership and an operational perspective. Every interview was recorded, transcribed, and analyzed. Moreover, a comprehensive number of notes was taken during the interviews. With the help of the

pre-study, we found that there is a lack of common understanding about the skills that are necessary for a DevOps team. Hence, we decided to conduct further investigation to obtain a more detailed picture about DevOps skill set for research and practice.

With the following exploratory study, we built up on the multiple-case study approach and investigated DevOps team members' construction within an ideal setting. The pre-study was the trigger for deciding to organize a workshop with IT consultant experts. We recognized that there are a lot of different skill sets in the investigated DevOps teams but a lack of a common understanding of a necessary skill set. Hence, we decided to build up on these findings and organize a workshop with IT experts. Therefore, we contacted an IT consultancy firm that is familiar with consulting projects pertaining to DevOps implementation. After a preliminary talk with two consultants, we reached an agreement about the content and identified participants for the workshop. Subsequently, we were able to conduct a personal DevOps expert workshop with nine IT consultants in October 2017. The IT consultants have different backgrounds, but are all working with DevOps topics. Our aim was to get a 360-degree view on the topic with the help of the workshop (Boehm et al. 2013). Figure 1 presents the workshop settings with the nine IT consultants. The workshop was moderated by two researchers. In sum, the figure presents the gender, working experience (years), current job role, and consultancy area of the IT consultants, namely manufacturing or digital business solutions (DBS).

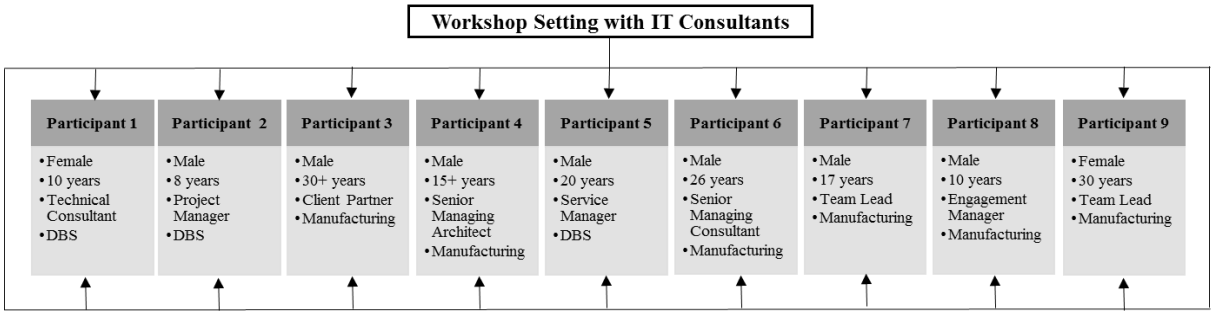

Figure 1. Workshop participants' demographics

As far as possible, workshops should start from a blank sheet of paper; issues and ideas should emerge through collaboration between practitioners and researchers (Howard et al. 2004). Thus, the findings of the workshop can be cross-referenced against the findings of preliminary case studies and the follow-up interviews and vice versa. The workshop meeting had a duration around two and a half hours. The researchers started with a short introduction and explained the goal of the workshop. To avoid bias, the researchers focused on the process of data collection, so as to moderate the workshop without influencing the opinions of the participants (Howard et al. 2004). In the workshop, the participants were asked to elaborate the skills required by a DevOps team in an ideal setting. We asked the experts to write down on cards the key skills that they see within an ideal DevOps team. Afterwards, the experts were asked to present their findings and pinned the cards with the key skills on a wall. Every expert expanded the wall with skills that were not mentioned before and discussed the findings with the others. Skills that were mentioned by more than one participant were prioritized. The skills were discussed in the group until no new insights into the topic could be gained. Hence, we had an iterative approach where skills were discussed and the findings were extended and verified by every presentation of skills by the IT consultants. The presentation of the findings and the discussion were recorded, transcribed, and photographed. The findings of the workshop were sent to the participants and we requested them to respond with feedback and verification within one week.

After conducting the workshop, we interviewed three other IT consultants of the company (Table 1) who were not participants of the workshop and asked them for the ideal setting of skills that should be implemented within a DevOps team. The aim was to verify and extend our findings. The interview partners could not be allowed to be influenced by our prior findings. Hence, we showed them the results of the workshop in the second half of the interviews. In the first half of the interview, the participants were asked to explain the skills they see in an ideal DevOps team. Then we asked the interviewees to supplement and comment on the results of the workshop. Thereafter, we presented an overview

of the achieved skill set of the workshop. These interviews provide some extensions and verifications of the workshops results. After three interviews, no new insights were given by the IT experts. All interview data and the workshop data were coded using the software NVivo 10 (Kude et al. 2014).

	Gender	Working experience	Job title	Industry
I1	Male	21 years	Managing Technical Consultant	Digital Business Solutions
I2	Male	29 years	Managing Senior Consultant	Financial Services
I3	Male	17 years	Team Lead	Manufacturing

Table 1. Interview participants' demographics

With the help of the workshop, an iterative approach for generating a skill set was used. As mentioned before, necessary skills were written down on cards and pinned to the wall. All nine participants contributed detailed information about why they felt a skill is important in a DevOps team. Furthermore, we went through transcripts of the follow-up interviews and coded them as well. We started the coding process following the guidelines given by Miles and Huberman (1994). Hence, we began with an open coding process. During the coding, the research team took notes to justify the coding section. Afterwards, the results were analyzed regarding key skills of DevOps members. Then, the research team compared its findings for each dimension to identify commonalities, relationships, and patterns. The focus was placed on the identification of the categories from the pre-study and the amplification and extension of the workshop results. Furthermore, we focused on the concrete skills that emerged during the data analysis of the expert workshop. Figure 2 depicts our research approach.

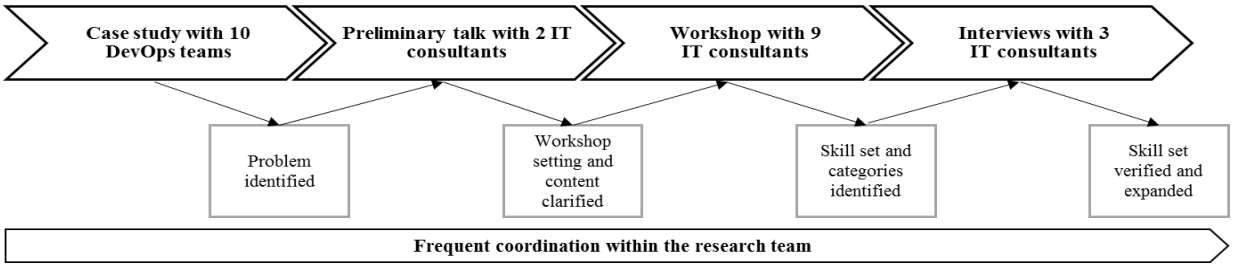

Figure 2. Research approach

During data analysis, the research team was able to derive key skill categories as topics for further subdivision into concrete skills to build a skill set. The concrete skills for ideal settings in DevOps teams were identified through the expert workshop and three post-processing interviews.

4 Findings

Our findings present a consolidation of the raw data with the same underlying ideas regarding skill categories, similar to the studies by Napier et al. (2009) and Klendauer et al. (2012). During the workshop, the participants mentioned some main categories or elements, and it was noted if similar detailed skills were mentioned by them, e.g. development skills. Additionally, the post-workshop interviews not only verified the skills but also automatically built core categories to sort the skills into them. After transcribing the audio data, the workshop and post-workshop interviews were coded regarding skills and core categories. Further, we extensively discussed the skills and categories in the research team, Finally, we were able to present seven core skill categories with 36 concrete skill items. The findings of our interviews for the pre-case study give insights into capabilities and skill categories of DevOps. The informants of the pre-study were unable to explain detailed skills and there was a lack of common understanding about which key skills seem to be necessary within a DevOps team. Hence, we decided to close this gap and present a common skill set for an ideal DevOps team to foster the general understanding of DevOps.

The several skill categories are now explained. The first one is **full-stack development**. We identified seven concrete skills within this category. During the pre-study, several cases highlighted that all activities of the software delivery lifecycle should be conducted by the DevOps team. The workshop participants highlighted that the comprehensive understanding of the different layers, tiers, and platforms is essential to work in a DevOps team.

Next, **analysis skills** are very important for DevOps team members. Analysis skills encompass IT operations skills (Gordon and Gordon 2002) that should now be learned by the complete cross-functional team. This is essential for monitoring, problem analysis, and management tasks. Further, all team members need skills for problem abstraction to determine where the problem could come from.

The next category we identified is **functional skills**. This category includes essential functional and consulting skills of the DevOps team. Functional skills are necessary to understand the business needs and achieve the desired benefits and goals (Liu et al. 2015). The team is now responsible for a service and thus has to manage it. This encompasses budgeting skills, work and time planning, and a deep understanding of the complete service process.

Decision-making skills are identified as another core category. DevOps members must be able to decide quickly, be self-confident, and take over responsibilities for possible failures. Decision-making is characterized by the identification of an action, the decision to take an action, determining when the action is finished, taking over the responsibility, and supporting this action (McAvoy and Butler 2009). In traditional IT organization, decision-making is a longitudinal process (Horlach et al. 2017; McAvoy et al. 2013) and now the team should be able to take over these skills for a concrete service.

The fifth category is **social skills**. These skills comprise the ability and willingness to share knowledge and communicate within the team. The IT consultants highlighted that a constructive feedback culture is essential for building a working relationship (Przybilla et al. 2018; Wagner et al. 2014) in DevOps teams. The willingness of the members to actively learn from one another enhances their knowledge of technology, users, and team activities. Hence, better software quality and performance can be achieved (Spohrer et al. 2012).

Testing skills are necessary to understand the general software-testing tasks needed to provide a new software feature. For avoiding software failures, software testing is an essential activity. With the help of software testing, the correctness of the code can be proved, security issues identified, and the quality of the software guaranteed (Onita and Dhaliwal 2011). For DevOps team members, it is necessary to implement testing skills, since new software features are delivered in very short time with the help of a high degree of automation (Fitzgerald and Stol 2017).

Advisory skills were identified as the seventh core category, because the workshop participants highlighted that there must be an awareness of the commercial consequences of breaking service level agreements (SLAs) or other agreements and commitments. Thus, team members have to know these agreements. DevOps team members have different backgrounds and are not always used to working with SLAs, especially in consultant projects. If there is a failure, people must work to solve the problem as fast as possible (Trusson et al. 2014). A breach of any agreement should generally be avoided. The following table presents an overview of the identified skill categories, their description, and the identified key skills.

Skill Category	Description	Skills
Full-stack development skills	Full-stack development skills are very broad and encompasses the complete stack and interests in all software technology. This is because the DevOps team is responsible for the service delivery lifecycle. Hence, familiarity with all layers of the software and platforms is present in the DevOps team.	• Learn overarching development abilities • Know the architecture of the software system • Acquire extensive understanding of the platform • Build platforms independently • Understand non-functional requirements • Know and understand tools and supporting processes • Know and understand continuous integration/development/delivery
Analysis skills	Analysis skills mostly concern IT	• Identify and resolve problems

	operation tasks like monitoring the system and the team's ability to comprehensively understand problem management (Gordon and Gordon 2002).	• Monitor the system operations • Analyze code and network problems • Abstract problems
Functional skills	Functional skills help to understand processes from a technical as well as from a business consultant view. This encompasses, apart from the technical knowledge about the service, a structured mode of operation and consulting the customers with regard to time and budget.	• Understand the complete processes • Understand the application • Build technological knowledge • Perform tasks in a structured way • Create consulting concepts • Record and understand customer demands • Build commercial project understanding
Decision-making skills	Decision-making skills address the fast and individual decision-making process (McAvoy et al. 2013). The team has to combine them with a degree of self-organization and willingness to take responsibility.	• Take responsibility for actions and wrongdoing • Encourage appropriate decision-making • Make decisions quickly • Enable self-organization • Develop dissolving power
Social skills	Social skills pertain to the interaction within the team as well as with the customer. Thereby, the team is able to collaborate and develop working relationship for successful working (Wagner et al. 2014).	• Approve feedback ability • Communicate according to target group • Learn intercultural communication skills • Show willingness to learn new skills • Work reactively and proactively within the team • Show willingness to share knowledge • Show willingness to learn from one another
Testing skills	Testing skills ensures that the software and new features work. Testing is necessary to ensure that a software meets the specific requirements (Onita and Dhaliwal 2011).	• Understand test automation functions • Automate tests • Understand functionalities for test management
Advisory skills	Agreements within a service function help to improve collaboration. These agreements need to be understood and met (Trusson et al. 2014).	• Understand agreements • Understand the commercial impact of agreements • Comply with agreements

Table 2. Skill categories, definitions, and skills for DevOps teams

5 Discussion

This paper is one of the first to elaborate a skill model for DevOps members; hence, it contributes with insights in the area of software development and operations. In this section, we discuss the identified DevOps-related skill categories. The order of the presented skills and categories reflects their importance, as mentioned by the workshop participants and interviewees. For example, full-stack development skills were mentioned by every participant of the workshop.

Full-stack development skills: This category was mentioned as the most important by the workshop participants. These skills visualize the development perspective of a DevOps team. For the setup of a DevOps team, a comprehensive knowledge of development activity is necessary. DevOps team members need to broaden their development skills to have comprehensive knowledge about the application. Hence, skills pertaining to the different layers, tiers, and platforms are necessary. Thus, full-stack development skills are necessary *"so that it makes sense if the application at any point faces problems […] I may have some issues with the application, but it's actually because my cloud infrastructure is not working properly" (8).* It is not sufficient for a DevOps team member to have only frontend or backend development knowledge. If a person is responsible for solving problems in a very short time,

comprehensive technical knowledge is necessary. In traditional IT functions, silos for development with members who have very highly specialized knowledge in one area are used (Horlach et al. 2017).

Analysis skills: The analysis skill category encompasses IT operation activities in particular and hence, comprises the Ops of DevOps. Analysis skills with focus on problem-solving are necessary, since the DevOps team is responsible for the complete service, and if a problem appears, it has to be solved. Problem-solving skills are critical within the software delivery process and developers have to adopt this knowledge to enhance performance (Ozer and Vogel 2015). Key skills for incident and problem-solving creativity are necessary (Trusson et al. 2014). The members have to wear pagers and should be willing to do night-support activities. Within an ideal DevOps team, every member is able to contribute with analysis skills. Analysis skills to manage problems and the corresponding skills are essential for the project success. IS development projects are connected with knowledge-intensive tasks including technical and application-based domain knowledge (Lin et al. 2015). Hence, there is a need to understand the analyzing skills within the DevOps team. If team members have to do nighttime support, all members need to have the ability *"to identify from where the problem comes and analyze or solve problems so that you can at least fix them till the next day" (8),* even if it is a person with no strong IT operational background.

Functional skills: The functional skill category includes comprehensive know-how about the complete service delivery process as well as consulting skills for collaboration with the customer (Przybilla et al. 2018)*"Process know-how about the development, operation, and business process is necessary" (8).* An ideal DevOps team must be clear about the functional processes. DevOps team members *"need functional knowledge about the application, or the team has to know the application from a functional perspective and should be able to assess it technically" (8).* A comprehensive knowledge of business processes and the ability to plan workloads and budget are essential in DevOps teams. Literature highlights that deeper understanding of the business functions is important for successful project collaboration. By including management and business knowledge into the team, solutions are delivered to avoid interruptions between different stages of planning, building, and running these stages (Fitzgerald and Stol 2017). Ideal DevOps teams are able to consult the customer, plan their working efforts effectively, and have a deep understanding of the development, operations, and business processes.

Decision-making skills: Decision-making skills refer to the ability of DevOps team members to make fast decisions, take responsibility if there is any failure and organize themselves within the team. The importance of decision-making skills are mentioned in existing literature with regard to agile software delivery (McAvoy and Butler 2009). Within an ideal DevOps skill setting, the team members are able to take over *"self-responsibility, enjoy decision-making, and adopt responsibility" (4).* Especially in the IT operations area, a lot of ad hoc decisions have to be made in *"stressful situations, when a major incident appears and a system is down" (5).* Usually, developers are not confronted with this fast decision-making process. Thus, organizations are under pressure to enhance the mindset and skills of developers so that they can fit in a DevOps environment. The members must *"keep calm and work with dissolving power" (I1)* when pressure from external environments appear or a major incident occurs, for example. Thus, within ideal DevOps teams, members must be able to react quickly to uncertainties and create an *"optimally organized" (I2)* team with a structured working mode.

Social skills: Social skills are necessary for interactions within the team as well as with the customer. Hence, connections between network actors, common language and code, and shared narratives, as well as the assets that create and leverage relationships should be investigated (Liu et al. 2015; Nahapiet and Ghoshal 1998). Social skills include skills like trust and knowledge-sharing, which are essential in ideal DevOps teams. The team members have to achieve a *"feedback ability, in both directions—so, to give feedback but also to accept it" (6).* This is connected with strong communications skills. Team member must be able to communicate in an audience-oriented manner. Usually, in traditional IT departments development and IT operations, people do not have a strong communication process (Horlach et al. 2017). In an ideal situation, the team members communicate, trust each other, and build a culture of communication. Furthermore, an end-to-end flow with customer demand is im-

plemented (Fitzgerald and Stol 2017) and the DevOps team members must consider this in their communications skills as well.

Testing skills: The DevOps movement is related to a high degree of automation (Fitzgerald and Stol 2017), e.g. test automation. Continuous testing includes the automation of some test processes and defines the priority of test cases with the aim to reduce the time between implementation and detection of errors and removal of root causes (Fitzgerald and Stol 2014). Thus, ideal members of DevOps team have an understanding of software testing, which includes *"special field testing" (I3)* and know-how to automate tests and manage test automation. Software testing includes late-stage system testing on a complete and integrated system to assess compliance with the requirements (Onita and Dhaliwal 2011). Team members need testing skills because *"it is a very important topic that should be addressed early so that people can manage the tests and the automation" (5).* In summary, comprehensive testing skills are important in ideal DevOps teams.

Advisory skills: The participants of the workshop and the interviews highlight that an understanding of SLAs and their commercial impact is a key skill for DevOps teams. Not every person in the IT is familiar with SLAs or other agreements. Hence, DevOps team members have to understand the impacts agreements, because the vendor has to pay fees in case of non-compliances (Hoermann et al. 2015): *"that you understand how SLAs work. But the developers often do not have that understanding" (6).* Team members with development background are not used to working with SLAs and need an awareness for them. Ideal skilled team members of DevOps environment can effectively react to ensure that the SLA is met and no monetary damage is incurred.

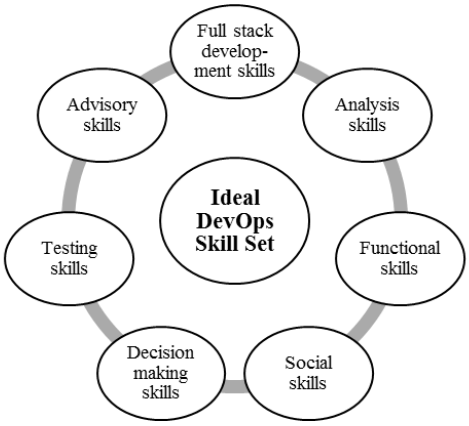

Figure 3. Skill categories of ideal DevOps teams.

In summary, we present a skill set for ideal DevOps team members with seven core categories and 36 skills. Several existing research works focus on requirements management skills (Chakraborty et al. 2010; Klendauer et al. 2012), customer representatives in agile projects (Matook and Maruping 2014), and IT project management skills (Napier et al. 2009). With the help of this paper, we contribute to existing literature by investigating the new phenomenon of DevOps. Compared to competencies in agile software development as depicted in existing research, e.g. Matook and Maruping (2014), this study shows DevOps skill sets by depicting the necessary operations skills like analysis skills and functional skills. Social-rational skills and development skills are also important in agile team settings, but the maintenance processes are usually neglected. We present a skill set for cross-functional DevOps teams that shows that skills from several areas—development, operations, and business—are important to work as a DevOps team.

IT organizations are confronted with the challenges of implementing the same skills in a very small cross-functional IT team. Therefore, a team of generalists is necessary. Team members have to leverage their knowledge in several areas in order to develop quality software (Spohrer et al. 2012). Workshop Participant 4 mentioned that *"at the current job market, I can't see where we can find such highly skilled people."* Furthermore, organizations need to build incentives that go beyond money to find well-educated people *"if you are not Facebook or Google" (1).* That means that not every company is

able to pay above average salaries to recruit this highly skilled people. Hence, organizations have to rethink their development programs for employees in order to train their existing IT staff with these full-stack development skills.

During the analysis of our findings, we found that these categories can have overlaps and dependencies that should be considered. For example, decision-making skills and social skills have dependencies, because the willingness to learn new skills helps the team members to develop a strong dissolving power. Furthermore, software development and testing are major parts of the software delivery lifecycle and have to be aligned to foster business success (Onita and Dhaliwal 2011). With the help of an ideal DevOps setting, these activities are embedded in one team. Every team member should have these skills to a certain degree. Furthermore, we have defined our categories with regard to the importance of the skills, as mentioned by the workshop participants and interviewees with the help of discussions within the research team.

Furthermore, the ideal DevOps setting is dependent on several issues, one of which is governance. If IT organizations work with third-party providers or contracts (Pflügler et al. 2016), a deep understanding of SLA is necessary. If your IT functions as an internal service provider for a business section, the focus will not lie on a strong SLA process but rather on other internal agreements. Within an internal DevOps organization (without providers), *"SLAs are quite complex"* because of the high *"process character"* that should be avoided in general within an agile DevOps environment (I1). Strong process orientation is typical for traditional IT functions. Within agile-oriented IT functions, the more processes are defined, the more agility is restricted (Horlach et al. 2017). DevOps approach enables the scaling of agility to the entire company (Gotel and Leip 2007). We have included advisory skills within our research since we talked to an IT consultancy firm; SLAs and contracts were reported to be foundations of their daily work and were mentioned several times in the workshop as well as in the individual expert interviews. Hence, priorities of the skill set will be different, depending on the conditions of organization and the structure of service delivery. Furthermore, implementing concrete DevOps skills within a team is strongly dependent on the IT function and the overall organizational management.

The full-stack development, analysis, and functional skills are rarely discussed in existing literature. These skills were assessed with the highest priority. The combination of roles that are responsible for planning, building, and running within a team has been emphasized for a long time (Markus and Keil 1994). Within an ideal DevOps team, every member should be able to undertake large parts of all these activities. Since this is a new approach and a great challenge for firms, our research provides a skill set that is helpful to identify and integrate skills to start implementing the DevOps concept.

However, organizations are confronted with the challenges of digital transformation and have to adapt agile-oriented working modes like the DevOps concept. This presents a tradeoff in reality, since the necessary skill set introduces immense requirements regarding IT staff that cannot be easily found on the job market or existing silo-oriented IT function. There is only a *"short training period into a high level of complexity" (I3)* of tasks. Hence, organizations have to take great efforts to train the personnel with the presented skills to develop competitive capabilities in the area of digital transformation.

5.1 Implications for theory and practice

In summary, our research represents a major contribution to research and practice. We deliver a framework with empirically grounded insights into the skills needed by an ideal DevOps team. These identified skill categories are crucial within this ideal DevOps team setting and essential for a successful software delivery lifecycle. Hence, we deliver an initial understanding of the attribute-based competency perspectives of DevOps team members and provide a new research in this area. The present research sheds light on a DevOps team profile of an IT function that has not been systematically analyzed in depth before.

In summary, our research highlights the specific profile of DevOps teams and presents a framework that is helpful for the individual team members as well as for the organization to develop core skills. Closer collaboration is necessary between the core activities of DevOps, development, and operations.

We identify DevOps-related skill categories of full-stack development, analysis, and functional skills as the most important. This shows that IT personnel with development as well as management and IT operation backgrounds have to expand their knowledge about these areas. Thus, with the help of the presented skills, we deliver concrete insights into team settings where planning, building, and running functions are integrated. We enhance the existing literature, which emphasizes the building of teams including business, development and implementations perspectives to foster performance (Markus and Keil 1994). Furthermore, the willingness to take self-responsibility and make decisions by the self-organized DevOps team and not by the management is a fundamental skill within an ideal DevOps team setting. This research focuses on the skills-as-attributes; how these skills affect the performance of DevOps teams is not in the scope of this study and should be considered by further research.

This research is the first step toward enhancing the understanding of DevOps skills, as mentioned in prior literature (Sebastian et al. 2017). We sort the identified skills into seven categories and hence provide a basis for further research. Further, we present differences and dependencies in existing research with regard to skills. Future studies can examine how these skill categories influence DevOps outcome. Moreover, interrelations between the skill categories and the several skills can be investigated. This study presents a starting point for an in-depth investigation of the field to enhance the theory.

The research presents interesting findings for practice as well. We deliver insights into how an ideal DevOps team can be set up. A set of key skills is provided by this research that can help IT managers to develop and integrate a DevOps teams. Our research provides a comprehensive overview of the skill that should be considered in DevOps team settings. We provide guidelines for the implementation of DevOps skills. Additionally, we give recommendations for designing trainings to develop highly skilled IT people. Courses for DevOps team members could be established to educate people through the organization's own IT function. This research can also be used to supervise or control project in with the DevOps approach is already used. This paper shows that practitioners increasingly need to be made aware of the DevOps concept and implement trainings and efforts to stay up-to-date. This research presents a comprehensive skill set in the case of ideal DevOps teams setup. Since these high-skilled IT people are not easy to find or train, further research should investigate how far every team member should be able to assist in every task. Furthermore, studies should investigate how DevOps teams can be supported through the IT function. Even if the team should work autonomously, there are interdependencies with other teams or the IT function. The identification of cross-sectional collaborations with other DevOps teams or with a traditional IT department is helpful for implementing DevOps teams.

5.2 Limitations

While interpreting the results, some limitations should be considered. This research focuses on the perception of IT consultants of one company. These consultants have worked in different projects with various levels of work experience. A large part of this research is based on the results of this workshop, which reduces the generalizability of our research. Further research should broaden this perspective by including a complementary study with more participants to substantiate the findings or find an additional company with a similar setting. Moreover, views of other stakeholders and internal DevOps teams might be interesting and uncover other characteristics of the skill set as well and should be investigated in further research. Furthermore, we present a skill set of an ideal DevOps setting, independent of the structure, industry, management, etc. In real-life context, there might appear some differences in the priority and characteristics of the several skills. Further, this research focuses on the IT perspective because we only talked to IT people. Agile development and DevOps team settings have a high impact on customers and business; hence, the research should be expanded through a business view as well.

6 Conclusion

This paper contributes to the understanding of skills of an ideal DevOps team. We used the concept of competencies and skills and identify attribute-based competencies that are characterized by the know-what (Klendauer et al. 2012; Napier et al. 2009) of DevOps team members. With the help of a multi-perspective research approach that comprises a case study research, workshops, and interviews for verifications, we were able to derive an ideal skill set for DevOps teams. Our findings show the importance of skills and skill categories to build effective and successful DevOps team. Since there exists less common view about DevOps key skills, we follow the path of prior literature (Fitzgerald and Stol 2017; Sebastian et al. 2017) to further investigate this phenomenon. This research enriches the understanding of several skills that were less defined in prior research. We identify seven core categories and report that three of them in particular—full-stack development, analysis, and functional skills—and above all the interaction between them, have not been widely discussed in prior IS literature.

Moreover, by analyzing and prioritizing our findings, this study highlights three major skill topics. This shows that a combination of strong development, operations, and management skills is necessary to successfully work within a DevOps team. Our findings expand existing literature in the field of skill as well as in the area of digital transformation—to be more concrete, DevOps and agile IT teams—and give practical implications as well. Existing research mainly focuses on agile and project management skills. The findings deliver a strong foundation for further research opportunities about the DevOps concept, possible relationships among the skill categories, several skills, and the effects of performance and outcomes of DevOps teams.

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