Mastering Interdisciplinarity in Work and Studies: A Psychological Perspective

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vorgelegt von

Anna Magdalena Claus

Berichter: Prof. Dr. Bettina S. Wiese

PD Dr. Malte Persike

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Zusammenfassung

Diese Dissertation untersucht Interdisziplinarität im Arbeits- und Studienkontext aus einer psychologischen Perspektive. In drei Manuskripten werden Wissen und Theorie zu individuellen Kompetenzen für die interdisziplinäre Zusammenarbeit und Wissensintegration in interdisziplinären Studiengängen erweitert.

Im ersten Manuskript wird mittels eines qualitativen Zugangs basierend auf der Critical Incident Technique ein Modell interdisziplinärer Kompetenzen entwickelt und in zwei darauf aufbauenden quantitativen Studien geprüft. Das Modell besteht aus den vier interdisziplinären Kompetenzen *Initiative zum Austausch, zielgruppenspezifische Kommunikation, Wissensintegration* und *Reflexion der eigenen disziplinären Perspektive*. Auf dem Modell basierend wurde eine Selbstberichtsskala entwickelt und mit exploratorischen Strukturgleichungsmodellen (ESEM) anhand einer Stichprobe von $N = 315$ interdisziplinär arbeitenden Erwerbstätigen getestet. Weiterhin wurde die konvergente Validität des Modells in Bezug auf motivationale Einstellungen gegenüber Interdisziplinarität und organisationalen Aspekten der Interdisziplinarität in einer Studie mit $N = 448$ Erwerbstätigen aus Wissenschaft und Praxis untersucht. Zusätzlich liegen die Einschätzungen von 153 interdisziplinären Kolleginnen und Kollegen der Studienteilnehmenden bezüglich interdisziplinärer Outcomes vor. Interdisziplinäre Kompetenzen konnten über generelle Teamarbeitskompetenzen hinaus Varianz in der Zufriedenheit und Effektivität von interdisziplinären Teams vorhersagen.

In Manuskript II liegt der Fokus auf der individuellen Kompetenz, Wissen zu integrieren, da dies ein definitorisches Merkmal interdisziplinärer Arbeit ist. Interdisziplinäre Teams müssen das Wissen aus verschiedenen Disziplinen integrieren, um das innovative Potenzial des fachübergreifenden Arbeitens zu nutzen. Integration auf Teamebene hängt von den Wissensintegrationskompetenzen der Teammitglieder ab. Hier wurden die

Wissensintegrationskompetenzen von *N* = 154 Erwerbstätigen, die zur Zeit der Erhebung interdisziplinär tätig waren, untersucht. Obwohl selbst- und fremdberichtete Wissensintegrationskompetenz statistisch nicht zusammenhingen, zeigten sich beide als relevante Prädiktoren für den Projekterfolg.

Im letzten Manuskript wird Interdisziplinarität im Kontext der Hochschulbildung betrachtet. Interdisziplinäre Studiengänge kombinieren verschiedene Fachdisziplinen, unterscheiden sich aber erheblich darin, wie sie dies tun. Im Mittelpunkt der Fragestellung steht hier Wissenssynthese, das bedeutet Wissensintegration und -verknüpfung auf Studiengangebene. Die erste Studie untersucht Wissenssynthese als einen Prädiktor für subjektive Studienoutcomes in einer Stichprobe von *N* = 306 Studierenden interdisziplinärer Studiengänge. Hier zeigte sich, dass soziale Integration den Zusammenhang zwischen Wissenssynthese und Studienzufriedenheit, Abbruchintentionen und Studienerfolgserwartung mediiert. In einer darauffolgenden zweiten Studie wurden die Prüfungsordnungen von 58 interdisziplinären Studiengängen, ergänzt durch Interviews mit den Fachstudienberatungen, hinsichtlich integrativer Lehrformate analysiert. Diese Informationen wurden verbunden mit den Wahrnehmungen von *N* = 2891 Studierenden aus diesen Studiengängen. Wahrgenommene Wissenssynthese war ein besserer Prädiktor für Studienoutcomes als die Umsetzung integrativer Lehrformate. Soziale und akademische Integration mediierten den Effekt von Wissensintegration auf Studienoutcomes. Darüber hinaus waren die Erwartungen der Studierenden bezüglich der Interdisziplinarität des Studiengangs mit Zufriedenheit, Abbruchintentionen und Studienerfolgserwartung assoziiert.

Zusammen genommen präsentieren die drei Manuskripte Erkenntnisse in der Psychologie interdisziplinären Arbeitens und Studierens. Die Dissertation betont die Bedeutung individueller Kompetenzen und Wahrnehmungen für die Erforschung von Interdisziplinarität.

Abstract

This doctoral dissertation investigates interdisciplinarity in work and studies from a psychological perspective. Three manuscripts aim at expanding knowledge and theory regarding individual competencies for interdisciplinary work and knowledge integration in interdisciplinary study programs.

In the first manuscript, a model of interdisciplinary competencies is developed using a qualitative approach based on the critical incident technique and then tested in two subsequent quantitative studies. The model comprises of the four interdisciplinary competencies *initiative for exchange, target group-specific communication, knowledge integration*, and *reflection of the own disciplinary perspective*. A self-report scale was developed using exploratory structural equation modeling (ESEM) and tested in a sample of $N = 315$ employees working interdisciplinarily. Furthermore, convergent validity with motivational attitudes towards interdisciplinary work and organizational aspects of interdisciplinary were studied in a sample with employees from academia and other industries ($N = 448$). Finally, a subset of $n = 153$ participants provided peer-ratings on interdisciplinary outcomes. Interdisciplinary competencies were able to explain variance above and beyond general teamwork competencies in team satisfaction and team effectiveness.

Manuscript II focuses on individual knowledge integration competency, as this is a defining aspect of interdisciplinary work. Interdisciplinary teams need to integrate knowledge from various disciplines in order to use the innovative potential of crossing disciplinary boundaries. Integration on the team-level depends on knowledge integration competency of the team members. The knowledge integration competencies of $n = 154$ employees working interdisciplinarily were examined. Although self- and peer-rated knowledge integration competency were not statistically related, both proved to be significant predictors for project success.

In the last manuscript, interdisciplinarity was studied in the context of higher education. Interdisciplinary study programs combine different disciplinary perspectives; however, they vary substantially in how they bring the disciplines together. Synthesis of knowledge, that is, the integration and interconnectedness of the disciplines, was at the center of this investigation. The first study examined synthesis of knowledge as a predictor for subjective study outcomes in a sample of $N = 306$ students who were enrolled in interdisciplinary study programs at that time. Furthermore, the relationship between synthesis of knowledge and study satisfaction, dropout intention, and achievement expectations was mediated by social integration at the university. In a subsequent second study, the curricula of 58 interdisciplinary study programs—complimented by interviews with academic advisors—were analyzed regarding the integrative teaching formats implemented in the program. This information was linked with the perceptions of $N = 2891$ students enrolled in the programs. Perceived synthesis of knowledge was a better predictor for study outcomes than the implementation of integrative teaching formats. Social and academic integration mediated the effect of synthesis of knowledge on study outcomes. In addition, students' expectations were associated with their satisfaction, dropout intentions, and achievement expectations.

Taken together, the three manuscripts present insights into the psychology of interdisciplinary work and studies. The doctoral dissertation highlights the importance of taking individual competencies and perceptions into account when studying interdisciplinarity as a phenomenon.

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General Introduction

"If you think of disciplines as organs, true interdisciplinarity is something like blood. It flows. It is a liquid. It is not contained. There is no inside and no outside."

Alice Gottlieb[1]

This doctoral dissertation examines how interdisciplinarity can be mastered in work and study contexts. The concept of interdisciplinarity builds on the existence of meaningful and distinguishable disciplines. Therefore, I will start by outlining the development and meaning of academic disciplines and why crossing disciplinary borders can be difficult. Different conceptions of interdisciplinarity are presented and common challenges that are associated with interdisciplinarity introduced. I propose a conceptual framework and describe the main research questions, before I shortly summarize the manuscripts which are the core of my doctoral dissertation.

The main part consists of three manuscripts entitled "Development and test of a model of interdisciplinary competencies", "Don't take it for granted: employees' individual knowledge integration competency in interdisciplinary work", and "How interdisciplinary are interdisciplinary study programs? On the importance of synthesis of knowledge for positive study outcomes".

The general discussion summarizes and integrates the main findings of the conducted research. In this section I reflect about strengths and limitations of my doctoral dissertation and discuss implications for future research.

[1] As cited in National Academy of Sciences, National Academy of Engineering, and Institute of Medicine of the National Academies (2005, p. 30). Alice Gottlieb is a professor of medicine and the director of the Clinical Research Center at the Robert Wood Johnson Medical School.

Disciplines and Their Development

Since classical antiquity, disciplines have been the core elements of science (Lerch, 2017). In those days, the liberal arts (*artes liberales*) provided a thorough study of the most relevant arts and sciences of that time for Roman and Greek gentlemen: grammar, logic, rhetoric, arithmetic, geometry, theory of music, and astronomy (and according to Varro, a Latin writer, also medicine and architecture; Lindberg, 1992). Here, disciplines were introduced as an organizing principle of science and natural philosophy (Lindberg, 1992). Although science and scientific disciplines have evolved tremendously since then, disciplines remain an integral part of science (Lerch, 2017).

Disciplines are not natural entities or based on theories, but rather on the issues of the world they tend to (Defila & Di Giulio, 1998; Mittelstraß, 1987). As a consequence, disciplines are a socio-intellectual construction and object to change and development (Mittelstraß, 1987). From today's perspective, disciplines appear somewhat arbitrary, as they do not necessarily align with present issues (Palmer, 2001). The ongoing differentiation of disciplines is described, on the one hand, as the loss of the uniformity of science, and on the other hand, as the expression of the growing knowledge of humankind and scientific advancement (Heid, 1989). Important factors in the growing number of scientific disciplines have been an increasing demand for precise and reliable information, rising effectiveness in creating and distributing scientific knowledge, and a growing number of educated practitioners (Heid, 1989). This led to a specialization based on the division of labor, because people were unable to keep up with the generated knowledge in all fields (Heid, 1989). Hence, the differentiation of disciplines is associated with scientific progress.

Why do Disciplines Matter? On Occupational Socialization and Occupational Identity

"Your planet is very beautiful", he [the little prince] said. "Has it any oceans?"

"I couldn't tell you," said the geographer. […]

"But you are a geographer!"

"Exactly," the geographer said. "But I am not an explorer. I haven't a single explorer on my planet. It is not the geographer who goes out to count the towns, rivers, the mountains, the seas, the oceans, the deserts. The geographer is much too important to go loafing about. He does not leave his desk."

The Little Prince by Antoine de Saint-Exupery[2]

Disciplines are categories to organize sciences. Although they seem somewhat arbitrary and are subject to change, they are not random entities. Instead, they are meaningful entities to the individuals in the academic system, both researchers and students, because they provide a source of community and identification. Lerch (2017, p. 18) describes the relationship between people and disciplines as interdependent, as "people make science and disciplines shape people".

Academic disciplines are defined by their respective scientific community, a body of available and agreed upon knowledge, relevant research questions, a set of methods, and a certain socialization (Defila & Di Giulio, 1998). As such, they build scientific subcultures with specific sets of rules, ideas, standards, and identities (Lerch, 2017). The common presumptions, values, and standards of each discipline enable smooth collaborations of people within this disciplines (Neumeier, 2007). At the same time, differences between disciplinary cultures, presumptions, and standards hinder collaboration across disciplinary borders (Sung et al., 2003). In the past, the metaphor of "academic tribes" was used to describe the distinct academic traditions, categories of thought, and shared concepts of theories, methods, and techniques of each discipline (Becher & Trowler, 2001). This

[2] de Saint-Exupéry (1943; chapter XV)

metaphor has been criticized for two reasons: (1) Scientific developments weaken the borders of traditional disciplines leading to a loss of disciplinary distinctiveness, and (2) knowledge, including disciplinary knowledge, changes steadily raising the question of the "territories" of the academic tribes (Brew, 2008). Nevertheless, disciplines remain important, in particular for individuals.

During academic and vocational training students get socialized in their disciplinary cultures, a process called enculturation (Bromme, Jucks, & Rambow, 2003). They read the literature that builds the body of knowledge in their disciplines, they learn the methods and approaches particular to their disciplines, and hence, they adopt specific disciplinary perspectives (Defila & Di Giulio, 1998; Lerch, 2017). The socializing aspect of work also stems from the norms and social ideas that are transmitted by work. Besides, occupational norms and values can be influential when the occupation or the discipline is not a central part of a person's value system (Frese, 1982).

Work is not merely a source for income, but a relevant part of peoples' lives and their identities, both in terms of an individual identity and as being a member of a social group (Maclean & Wilson, 2007). An occupational identity is a major component of an individual's overall sense of identity, that is, of one's perception of the own person in terms of "wholeness" (Skorikov & Vondracek, 2011). Occupational or vocational identity refers to the "conscious awareness of oneself as a worker" (Skorikov & Vondracek, 2011, p. 693), but also to a particular occupation or work role one has chosen, and to a lesser degree to the organization one works for (Baruch & Cohen, 2007).

The development of occupational identity in crafts and trade businesses is clearly linked to the successful completion of an apprenticeship. Apprenticeships provide people with basic skills to sustain an income, but also serve as a means to socialize a person into a community of practice and to internalize the conduct and outlook of that community of

practice (FAME Consortium, 2007). Entering the community of practice and committing to their values after years of training and socialization is connected to forming an occupational identity (Finegold & Matousek, 2007). Through role ascription and role taking, people learn to refer to themselves in terms of occupation (Frese, 1982).

Socialization in an occupational community during extensive training serves as an important element for developing an occupational identity (FAME Consortium, 2007). This should be true for both communities of practice and academic disciplines, because each academic discipline has their own scientific community (Defila & Di Giulio, 1998) with specific norms and values. For individuals who have made an occupational commitment, for example through means of studies or vocational training, it is quite likely that they experience an occupational identity achievement status, that is, a strong commitment to self-chosen occupational goals and values (Skorikov & Vondracek, 2011).

To sum it up, disciplines are meaningful entities both in science and in practice. Disciplines and occupations form collective social identities. People identify with their disciplines and with the values and norms of the communities they represent. They internalize the standards and procedures during academic or vocational training.

The Promise of Interdisciplinarity

"We are not students of some subject matter, but students of problems. And problems may cut right across the borders of any subject matter or discipline"

Karl Popper[3]

Aging, climate change, ending poverty, food, migration, and water are only a few of the global issues the United Nations (2019, not paginated) describe as problems that "transcend national boundaries and cannot be resolved by any one country acting alone". One might add that these issues cannot be resolved by any one discipline working alone either.

[3] Popper (1962, p. 66)

Academic disciplines do not necessarily align with today's global issues and current research interests (Palmer, 2001). As a consequence, disciplinary borders have to be crossed to adequately work on those issues. For some, this can also be seen as an opportunity to overcome disciplinary borders—if not disciplines themselves—and restore uniformity of science (Heid, 1989).

There are many variations of working across disciplinary borders—multidisciplinarity, crossdisciplinarity, transdisciplinarity, and interdisciplinarity—each with a different meaning. The terms *multidisciplinarity* and *crossdisciplinarity* describe collaborative efforts in which people with different disciplinary backgrounds are involved. Here, a juxtaposition of different disciplinary perspectives is pursued to foster wider knowledge and methods (Klein, 2010). This approach is additive in nature, as the contributions from each discipline remain distinguishable. With regard to *transdisciplinarity*, there is no single definition. On the one hand, transdisciplinarity is referred to as an approach that overcomes disciplines and creates a global system of knowledge that goes beyond disciplines. On the other hand, the term transdisciplinarity is used to describe projects that include actors from different disciplines, different occupations, and sectors of society, such as academia and practice (Repko, 2012).

In contrast to additive approaches, the key defining element of *interdisciplinarity* is integration (Repko, 2012). Klein and Newell (1996, p. 3) define interdisciplinarity as "a process of answering a question, solving a problem, or addressing a topic that is too broad or complex to be dealt with adequately by a single discipline or profession [… It] draws on disciplinary perspectives and integrates their insights through construction of a more comprehensive perspective". Here, links between disciplinary perspectives are actively sought to create synthesis (Klein, 2010). In contrast to multidisciplinarity, in which disciplines complement each other, interdisciplinarity strives for an "intermeshing" of

disciplinary perspectives (Hübenthal, 1994). The integrative approach of interdisciplinarity is assumed to particularly foster innovation. In this dissertation, I employ a rather broad understanding of interdisciplinarity to include a range of variations of working or studying across disciplinary borders, following Moran's (2010, p. 14) understanding that interdisciplinarity is "any form of dialogue or interaction between two or more disciplines". This very broad conception will be the basis for this dissertation, however, in the following manuscripts this will be more closely dissected, for example, in accordance with participants' own understanding of their interdisciplinary work (e.g., degree of integration, disciplinary closeness).

Crossing disciplinary borders is expected to generate exciting scientific results and innovative solutions (Sung et al., 2003). Since the 1960, national funding agencies around the globe have promoted interdisciplinary research and education programs to foster global competitiveness, national security, and economic prosperity (Bruce, Lyall, Tait, & Williams, 2004; DFG, 2013; Huutoniemi, Klein, Bruun, & Hukkinen, 2010; National Academy of Sciences et al., 2005).

The motivations to pursue endeavors across disciplinary borders are manifold. Some reasons are closely linked to research and specific subject matters, for instance, research in cognitive neuroscience requires experts from different disciplines (Epstein, 2005). Other initiatives can best be described as being politically motivated, for example, the National Academy of Sciences et al. (2005) sees the need to solve societal problems and produce new, revolutionary technologies as central drivers for interdisciplinarity (Lerch, 2017). In addition, Bruce et al. (2004) point out that interdisciplinary research often is exciting and stimulating due to the new knowledge researchers decipher when interacting with people from a different disciplinary background.

Challenges of Interdisciplinarity

"There is this long-standing call for this type of research. The question we have to ask ourselves is, what is the problem? Why isn't this proceeding at a more rapid rate?"

Cliff Gabriel[4]

The outcomes or products of interdisciplinarity are seen as potentially very innovative, yet the process of interdisciplinary work is challenging on different levels. The problems interdisciplinary work and studies might cause are directly linked to the existence of disciplines – if there were no classification of disciplines, no disciplinary borders would have to be overcome (Hübenthal, 1994). Interdisciplinarity can be challenging for (1) the individuals involved and (2) when trying to organize work and projects. Additionally, it can also influence (3) the quality of the outcomes.

Looking at (1) individuals, interdisciplinary collaborations can challenge their identities. In interdisciplinary interactions approaches, methods, and theories associated with a person's discipline and engrained in their occupational identity, might be questioned (Bromme, 2000). This can lead to refusal of ideas from other disciplines (so called not-invented-here syndrome; Antons, Declerck, Diener, Koch, & Piller, 2017). As people might be unaware of some aspects of their occupational identity (Hübenthal, 1994), they might struggle to explain themselves and to "protect" these disciplinary habits. Therefore, interdisciplinarity can be experienced as a threat to one's identity (Lindvig & Ulriksen, in press). Davis (2007, p. B9) describes this process as "dismantling some cherished rules of their [the other discipline's] game". However, researchers who successfully work interdisciplinarily might also develop a new occupational identity independent of a discipline: a transdisciplinary scientific identity (Hagoel & Kalekin-Fishman, 2002).

[4] As cited in National Academy of Sciences et al. (2005, p. 22). Cliff Gabriel is the deputy associate director of the White House Office of Science and Technology.

In addition, the pursuit of interdisciplinary research endeavors puts risks on a junior researcher's academic career (Millar, 2013). While exciting and promising research questions might cross disciplinary borders, the academic system is highly structured by disciplines. Therefore, some researchers perceive a tension between interdisciplinary research and a tenured academic career (Rhoten & Parker, 2004). To some degree, this conflict can be explained by difficulties to find high-quality publishing outlets for interdisciplinary research (Millar, 2013).

With regard to interdisciplinary education, the question arises how students who do not yet have a disciplinary identity, can develop an occupational identity in an interdisciplinary study program (Finegold & Matousek, 2007). Some research emphasizes the importance of a balance between disciplinarity and interdisciplinarity (Newell, 1992; Spelt, Biemans, Tobi, Luning, & Mulder, 2009). Finegold and Matousek (2007) present the case of new bioscience programs (e.g., systems biology, biotechnology) and argue that new interdisciplinary occupational identities have been established here, because graduates could easily find a job. They interpret success at the job market as indicators for an established new occupational identity. From my point of view, this perspective falls short in explaining students' experiences and perceptions of committing to a scientific community (see FAME Consortium, 2007).

Interdisciplinarity also poses challenges for (2) organizing projects and teamwork. Integrating different disciplinary perspectives requires exploring those thoroughly which takes time (van Knippenberg, De Dreu, & Homan, 2004). Hence, interdisciplinary work generally takes longer than disciplinary work due to increased coordination efforts (Jooß, Thiele, Vossen, Richert, & Jeschke, 2015). New collaborations with colleagues whom one has not worked with before increase the risk to fail (Kaufmann, 1987). Here, a lack of common ground can explain difficulties in collaboration and, in particular, in communication

(Bromme, 2000; Clark, 1996). Furthermore, the development of a shared knowledge base has been described as particularly difficult in interdisciplinary teams (Steinheider, 2012). This finding has been explained by different mental models in the disciplines (Maynard & Gilson, 2014). Regarding organizational matters of interdisciplinary projects, Defila, Di Giulio, and Scheuermann (2006) have created a handbook with common pitfalls and best practice examples.

Finally, (3) the quality of interdisciplinary results has been criticized (Jacobs & Frickel, 2009). The breadth of interdisciplinary research often comes at the cost of depth. Interdisciplinary research has been said to be superficial and conceptually confused (Berger, Winiwarter, Dressel, & Heimerl, 2014). A challenge for interdisciplinary work is to "steer clear of amateurism" (Davis, 2007, p. B9) and to comply with scientific standards. As innovation and scientific progress have been put to the fore as central drivers for interdisciplinary research the "dubious quality" (Jacobs & Frickel, 2009, p. 52) of results severely limits the potential outcomes and, thus, questions interdisciplinary endeavors in general.

Mastering Interdisciplinarity: Central Research Questions

"The calls we got from grantees in our interdisciplinary science program were not about extensions to the grants or budget. They were, "could you help us figure out how to get that collaboration to work more effectively?"

Barry Gold[5]

This doctoral dissertation focuses on a psychological perspective on mastering interdisciplinarity in work and studies. Although much has been written about interdisciplinarity, there is a lack of empirical, psychological research on this matter. This is surprising, as many challenges in interdisciplinary work and studies are psychological in

[5] As cited in National Academy of Sciences et al. (2005, p. 129). Barry Gold is the program officer for conservation and science at the David and Lucile Packard Foundation.

nature – they concern human perceptions, experiences, and behaviors and attempt to analyze, predict, and change these in order to create effective and satisfactory work environments. One exception to this is Bromme's (2000) idea of a psychological perspective on interdisciplinarity. Bromme (2000) suggested that psychological research on interdisciplinary work should concentrate on structural, cognitive differences between disciplines and communicative styles. While there is little doubt that communication and structural differences are important factors in interdisciplinary work, this dissertation takes a broader psychological perspective on how interdisciplinarity can be a success.

My doctoral dissertation consists of three manuscripts which shed lights on different aspects of interdisciplinarity. Manuscript I and II concern the question how individuals can master interdisciplinarity in the workplace. Manuscript III focuses on integrative learning experiences in interdisciplinary study programs. The last two manuscripts concentrate on the integrative facet of interdisciplinarity.

Consistently, this doctoral dissertation addresses the question how challenges and demands that come hand in hand with interdisciplinarity—from communicative hurdles (Bromme, 2000) to challenges in developing a shared knowledge base (Steinheider, 2012)—can be managed both on the individual and the organizational level. I examine preconditions for mastering interdisciplinarity but also outcomes on the individual, the interpersonal, and the organizational level. In the following paragraphs, I will outline the central research questions of this doctoral dissertation and present a framework to organize the ideas and findings.

How can individuals master interdisciplinary work?

Interdisciplinary work is teamwork, yet a special kind of teamwork. And while challenges to interdisciplinary work present on different levels, most research has focused on how interdisciplinary teamwork can be organized. Little attention has been paid to the

question, how and why individuals differ regarding their effectiveness in handling interdisciplinary endeavors. Therefore, the first two manuscripts focus on the behaviors, experiences, and performances of individuals involved in interdisciplinary teamwork. Here, interdisciplinary competencies, which are skills and abilities that allow people to perform effectively in interdisciplinary environments, are of core interest to me. In sum, this doctoral dissertation takes the perspective that individuals can master interdisciplinary work by developing certain competencies enabling them to cope with demands and challenges specific to interdisciplinary teamwork.

Precedents of individual effectiveness in interdisciplinary work. In this doctoral dissertation, different factors that might contribute to the development of competencies for interdisciplinary teamwork are examined. Individuals who engage in interdisciplinary work and are faced with complications and challenges have two options. They might either retreat to their own disciplinary field and refrain from any integrative effort, thus rendering the collaboration a multidisciplinary one, or they can attempt to resolve conflicts and misunderstandings among different disciplines which in turn might teach them skills for future successful interdisciplinary interactions.

Aspects on the individual, interpersonal, and organizational level might determine whether people proactively engage in developing interdisciplinary competencies. On the individual level, the role of interdisciplinary work for the employee (e.g., interest in interdisciplinary work, significance of interdisciplinary interactions for the job task) and previous experiences with interdisciplinarity, in the sense of a transferability of competencies, as well as motivational prerequisites are studied in this dissertation. In addition, on the interpersonal-level, that is, among the interdisciplinary team members, task-interdependence and on the organizational level managerial support for interdisciplinarity are studied with regard to the development of interdisciplinary competencies.

Interpersonal and organizational outcomes of individual competencies for interdisciplinarity. Interdisciplinary competencies of individuals involved in interdisciplinary work, that is, individual differences in the effectiveness to handle interdisciplinary endeavors, should be reflected in positive work outcomes (Brandstädter & Sonntag, 2016). This doctoral dissertation examines team effectiveness and team satisfaction as interpersonal outcomes of interdisciplinary competencies on the individual level. In addition, competent team members are thought to enable smooth and thus successful collaborations, which should manifest in project success on the organizational level.

How does knowledge integration happen? Who makes it happen?

"Integration is widely viewed as the litmus test of interdisciplinarity."

Julie Thompson Klein[6]

The core defining element of interdisciplinarity is integration. The exploration and integration of separate bodies of knowledge is the essence of interdisciplinarity. Teams that engage in knowledge integration perform better and find more creative solutions to given problems (Hoever, van Knippenberg, van Ginkel, & Barkema, 2012; Homan, van Knippenberg, van Kleef, & De Dreu, 2007; Luan, Ling, & Xie, 2016). The model of knowledge integration by Repko (2012) describes three components of the integrative process: (1) identifying conflicting insights and theories, as well as locating their sources, (2) creating common ground between different and possibly conflicting disciplinary concepts and theories, and (3) constructing a comprehensive understanding of the problem. While integration as a process has been studied, little is known about the initiation of knowledge integration in real world interdisciplinary teams. Therefore, it is important to take a closer look at knowledge integration in interdisciplinary work.

[6] Klein (2010, p. 112)

Literature on performance in diverse teams has highlighted individual differences in the competency of integrating. In this context, integration refers to knowledge exploration and integration among different groups whether those are defined by surface variables (e.g., age or gender) or deep variables (e.g., educational background). For instance, van Knippenberg et al. (2004) refer to the skills and abilities for effective work in diverse teams as characteristics individuals bring into the team. As interdisciplinarity requires integrative efforts, I study interindividual differences in knowledge integration competency.

Furthermore, knowledge integration is also relevant in educational settings. The integration of separate bodies of knowledge within a study program is crucial to the goal of interdisciplinary study programs, that is, to provide an education that allows crossing interdisciplinary borders (Armstrong, 1980). While interdisciplinary integration is often left to students, this doctoral dissertation sheds a light on organizational-level knowledge integration in interdisciplinary study programs, so called synthesis of knowledge. While oftentimes integration and synthesis are used as synonyms (Repko, 2012), I prefer to use integration as a more comprehensive term and synthesis of knowledge to refer to organizational integration and interconnectedness of disciplinary perspectives within an interdisciplinary study program (Armstrong, 1980).

Interdisciplinarity in work and studies.

„Who hasn't studied *interdisciplinarily, cannot do* research *interdisciplinarily."*

Jürgen Mittelstraß[7]

Interdisciplinarity poses challenges both for employees in the work setting and for students in higher education settings. While interdisciplinary work threatens interdisciplinary identities and requires to integrate established interdisciplinary perspectives (Lindvig &

[7] Mittelstraß (1987, p. 157). German original: "Wer nicht interdisziplinär *studiert* hat, kann auch nicht interdisziplinär *forschen*."

Ulriksen, in press), the challenge in interdisciplinary study programs lies in the development of an interdisciplinary identity and the integration of newly learned concepts (Armstrong, 1980). The call for interdisciplinary education is based on the belief that graduates of interdisciplinary study programs are particularly well prepared to work on the grand challenges of today (Lattuca, Voight, & Fath, 2004). However, no research known to me has shown that graduates of interdisciplinary study programs are better equipped to engage in interdisciplinary research. This doctoral dissertation takes both settings into account, work and studies, and examines the perspectives of the individuals involved.

Conceptual framework.

Figure 1 depicts the central research questions of this dissertation. The rows refer to different levels of examination—individual, interpersonal, and organizational. On the left side of the figure, my studies in the work setting are pictured, while the right shows the educational setting. The model of interdisciplinary competencies builds the core of the doctoral dissertation, however, knowledge integration has also been studied on the organizational level in the educational context.

Summary of Manuscripts

This doctoral dissertation is built on three manuscripts. The next sections shortly summarize the manuscripts.

Development and test of a model of interdisciplinary competencies.

This manuscript contains three studies which revolve around the question which individual level competencies enable successful interdisciplinary collaboration. As interdisciplinary collaborations are often experienced as particularly difficult (Epstein, 2005) many interdisciplinary projects evolve to be rather multidisciplinary in nature which impacts their ability to create novel solutions for central problems.

Study 1 uses a qualitative approach based on the critical incident technique (Flanagan, 1954) to identify specific competencies for interdisciplinary collaborations. Based on

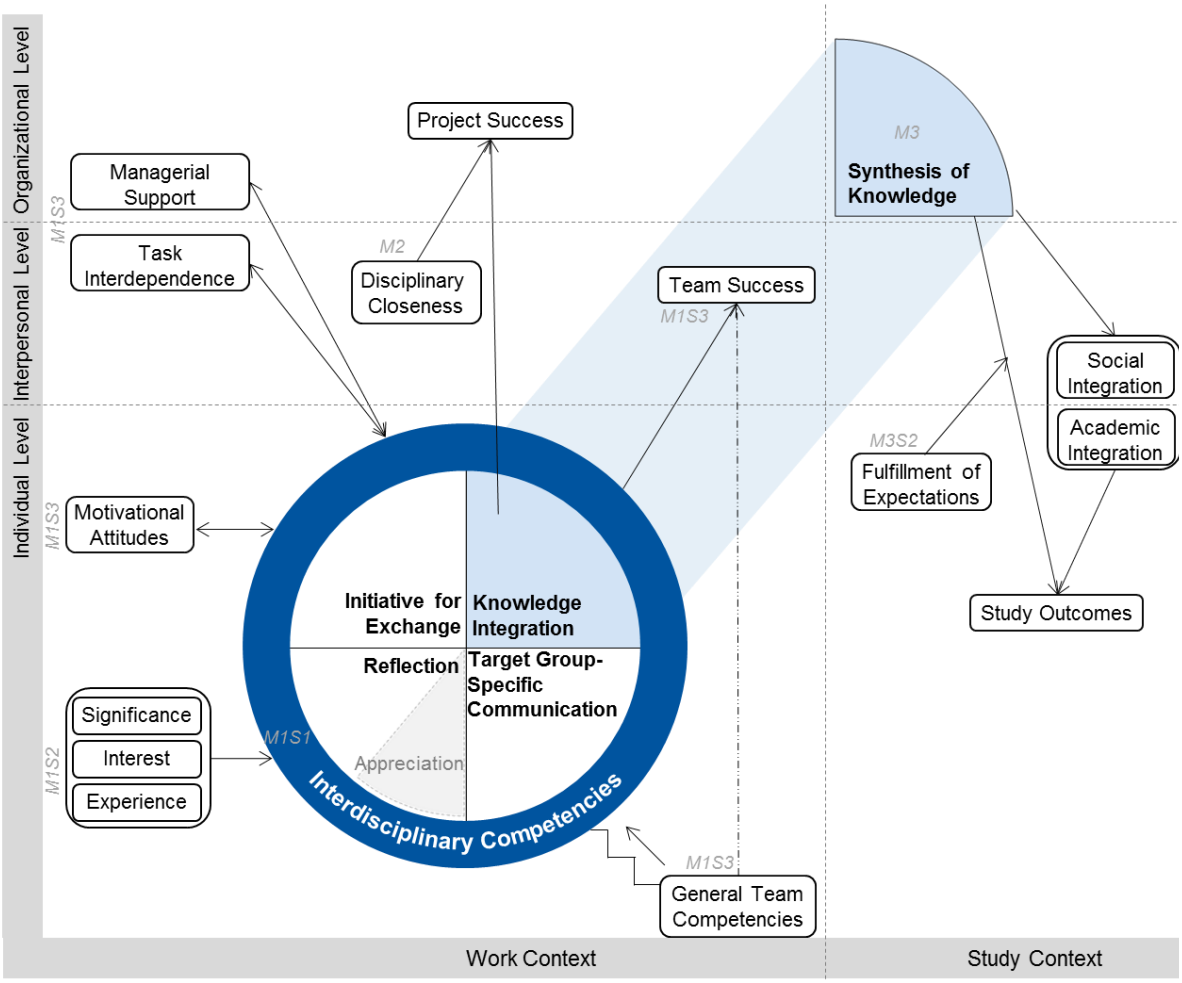

Figure 1. Conceptual framework for research questions. The rows differentiate the individual, interpersonal, and organizational level. Research in the work context is shown on the left and educational settings are on the right. The model of interdisciplinary competencies with a focus on knowledge integration is the center of the doctoral dissertation. Synthesis of knowledge can be understood as knowledge integration on the organizational level in the study context. The respective manuscript and studies are set in italics.

interviews with expert practitioners with extensive experience in interdisciplinary work, behaviors that were beneficial for interdisciplinary outcomes were clustered to form the four

interdisciplinary competencies (1) *initiative for exchange*, (2) *target group-specific communication*, (3) *knowledge integration*, and (4) *reflection and appreciation*.

In Study 2 we developed and tested a self-report scale for interdisciplinary competencies. Based on a sample of $N = 315$ employees with experience in interdisciplinary work, items were evaluated using exploratory structural equation modeling (ESEM; Asparouhov & Muthén, 2009) to represent the competency dimensions initiative for exchange, target group-specific communication, knowledge integration, and reflection and appreciation. While the first three competency dimensions could be modeled based on the self-report data, the factorial structure suggested revising the compound dimension reflection and appreciation. Hence, the reviewed model only includes *reflection of own disciplinary perspective* and not appreciation. Furthermore, as a first model validation, convergent validity with interest in interdisciplinary work, significance of interdisciplinarity for the own task, and previous experience were studied.

Study 3 served as a validation study. As academics were overrepresented in the first studies, Study 3 showed that the model generalizes for a more diverse sample ($N = 448$ employees with experience in interdisciplinary work). In addition, the convergent validity with regard to motivational attitudes toward teamwork (interest, self-efficacy, and a general preference for teamwork) and organizational aspects of interdisciplinary work (managerial support for interdisciplinarity and task interdependence) were studied. Most importantly, the study revealed that self-reported interdisciplinary competencies predict interdisciplinary outcomes above and beyond general teamwork competencies. For this purpose, data of $n = 153$ participants was complemented by data from interdisciplinary colleagues who gave a peer-report on the outcomes team satisfaction and team effectiveness.

To put it in a nutshell, the manuscript “Development and Test of a Model of Interdisciplinary Competencies” emphasizes individual-level contributions to successful

interdisciplinary work by examining interdisciplinary competencies of employees, their prerequisites, and central outcomes.

Don't take it for granted: employees' individual knowledge integration competency in interdisciplinary work.

The second manuscript sheds a light on knowledge integration as an individual level competency. Previous studies have shown that knowledge integration on the team level is associated with positive performance outcomes of heterogeneous teams. We argue, however, that knowledge integration on the team level depends on the competencies of team members to elaborate and connect information from various sources. Here, the knowledge integration competencies of $N = 154$ target persons are reported by themselves and by a peer with whom they worked interdisciplinarily at the time. Self- and peer-report are not statistically related, but both prove to be significant predictors for peer-rated project success.

Based on the common ground theory by Clark (1996), the role of disciplinary closeness of the dyads is examined. As some disciplines share theories, methods, and core elements, the question arises whether interdisciplinary work among related disciplines require knowledge integration competency to the same extend as in more distant disciplines. Moderation analyses revealed that disciplinary closeness did not moderate the effect of knowledge integration competency on project success, neither could it explain the lacking correlation between self- and peer-reported competency.

How interdisciplinary are interdisciplinary study programs? On the importance of synthesis of knowledge for positive study outcomes.

Manuscript III resolves around interdisciplinary study programs, which aim at educating students to work across disciplinary borders. Therefore, students need to learn to

integrate knowledge from different disciplines. Study programs can support students in this endeavor by creating synthesis of knowledge in the study program, that is, by offering integrative courses and addressing the challenges of bringing together different disciplinary perspectives.

The framework of interdisciplinarity in higher education by Spelt et al. (2009) postulates students' characteristics, learning environment, and the learning process as interacting components that explain interdisciplinary study outcomes. With regard to the learning environment, Armstrong (1980) differentiates four stages of synthesis of knowledge in the study program. This manuscript focuses on the research question how synthesis of knowledge in the study program is linked with study outcomes.

Study 1 (N = 306) examines the relationship between perceived synthesis of knowledge in the study program and the subjective study outcomes study satisfaction, dropout intentions, and fulfillment of academic achievement expectations. These direct effects are mediated by students' interactions with faculty and peers: as students struggle to see how distinct disciplinary classes form a comprehensive study program, they might also have difficulties adjusting to the university as a social system. Social integration, however, has been shown to influence study success and retention (Tinto, 1993).

Study 2 (N = 2891 students in 58 study programs) was conducted at a single university with a substantial offer of interdisciplinary study programs. Here, information from actual curricula and academic counselors on synthesis of knowledge in the study programs was linked with students' perceptions. Again, perceived synthesis of knowledge in the study program was associated with more positive study outcomes. This relationship was mediated by both social integration and academic development as part of academic integration (Tinto, 1993). In addition, the fulfillment of students' expectations regarding the

interdisciplinarity of the study program moderated the effect of perceived synthesis of knowledge on academic achievement expectations.

These studies underline the importance of students' perception of their study programs: Perceived synthesis of knowledge is associated with more positive study outcomes.

Development and Test of a Model of Interdisciplinary Competencies

Anna M. Claus & Bettina S. Wiese

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Abstract

Interdisciplinary work offers both innovative potential and challenges in collaboration. The present paper summarizes three studies intended to foster a psychological, competency-focused understanding of interdisciplinary work. In a qualitative interview study (Study 1) with expert practitioners of interdisciplinarity, we used the critical incident technique to explore which individual competencies support interdisciplinary collaborations and improve innovative outcomes. Focusing on competencies specific to interdisciplinarity, we derived a four-dimensional model. In Study 2, we tested the model dimensions (1) *initiative for exchange*, (2) *target group-specific communication*, (3) *knowledge integration*, and (4) *reflection* in a quantitative survey study among $N = 315$ employees who were experienced in interdisciplinary work using exploratory structural equation modelling. Finally, in Study 3, we studied the convergent and divergent validity of interdisciplinary competencies as well as their role in predicting team outcomes. Here, a dyadic sample of $N = 448$ target persons and $N = 153$ interdisciplinary colleagues were surveyed. We discuss possible applications for the new model of interdisciplinary competencies and the developed self-report instrument.

Keywords: interdisciplinary competencies; critical incident technique; exploratory structural equation modelling; mixed-method; validation

Development and Test of a Model of Interdisciplinary Competencies

Interdisciplinary projects aim for innovation both in academia and the private sector by attending to complex tasks that cannot be adequately addressed by a single discipline alone (Sung et al., 2003). But many interdisciplinary projects cause frustration among team members who find this kind of teamwork particularly difficult (Epstein, 2005). As a result, projects are often divided into separate disciplinary sub-projects, and the innovative potential of integrating different disciplines gets lost (Rogers, Scaife, & Rizzo, 2005).

Interdisciplinarity is a special case of collaboration. During academic training and work practice, students and employees become socialized in a disciplinary culture and adopt its disciplinary perspective which influences their thinking about tasks, possible solutions, and methods (Reich & Reich, 2006; Repko, Szostak, & Buchberger, 2014). The disciplinary background is a deep-level characteristic relevant for teamwork. In the past, researchers have studied specific challenges that interdisciplinary work poses such as communication barriers (Bromme, 2000) and knowledge integration problems (Steinheider, Bayerl, Menold, & Bromme, 2009). Interdisciplinary work thus poses specific demands on employees.

While previous work has highlighted organizational means and team level characteristics to make functionally diverse and interdisciplinary collaborations successful (Cheung, Gong, Wang, Zhou, & Shi, 2016; Cronin & Weingart, 2007; van Ginkel & van Knippenberg, 2008), competencies of involved employees have received little attention. Nevertheless, individual competencies of team members are an important factor for flourishing interdisciplinary collaborations (Bronstein, 2003; Epstein, 2005). Existing concepts for general teamwork competencies (e.g., Stevens & Campion, 1994) do not address unique competency requirements for interdisciplinary work. Therefore, they do not provide sufficient guidance in analysing how individuals can positively influence interdisciplinary work. Understanding individual competencies and their impact on interdisciplinary

collaboration is necessary to develop means to improve project outcomes and to utilize innovative potentials.

We applied a mixed-methods design to develop and test a model of unique interdisciplinary competencies. In doing so, the present studies contribute to theory and knowledge in research on interdisciplinarity in at least two ways: First, we contribute to the theoretical understanding of interdisciplinary collaborations by identifying relevant competency dimensions for interdisciplinary work. Thus, we extend literature on competencies for teamwork situations (Stevens & Campion, 1994) to the unique requirements of interdisciplinarity. Our second contribution is the development of a model-based instrument to measure interdisciplinary competencies to foster future research.

Interdisciplinary Collaboration

Interdisciplinarity is defined by a high degree of integration of different disciplinary perspectives (Repko et al., 2014). Disciplinary perspectives represent established bodies of knowledge and modes of thinking within one academic or occupational field. They facilitate work processes within a discipline; however, they also hinder cooperation across disciplines (Sung et al., 2003). Thus, in interdisciplinary collaboration, information, data, methods, and theories associated with the involved disciplines need to be integrated to form a shared project. In this regard, interdisciplinarity differs from other forms of collaboration between disciplines (e.g., multidisciplinarity) which juxtapose disciplinary perspectives (Newell, 2001; Szostak, 2002).

Interdisciplinarity is a special form of functional diversity. Interdisciplinary teams are often built around a certain topic or research question. To deal with the issue at hand, individuals from different disciplines and their expertise are required (e.g., for product development of a shampoo, a chemist, a dermatologist, a beautician, a production engineer, and a business administrator might work together). In diverse teams, socially shared

cognition has been shown to influence the process of elaborating distributed information (van Ginkel & van Knippenberg, 2008). The development of shared mental models is supported by increased interaction and communication (Maynard & Gilson, 2014). However, communication in interdisciplinary teams is challenging, as shared communal experiences based on discipline are lacking. Consequently, interdisciplinary teams need to elaborate and negotiate their common ground that is the basis of mutual knowledge and beliefs (Clark, 1996). In other words, smooth collaboration in interdisciplinary teams requires increased competencies of team members, particularly regarding the communication domain, to create a common ground and shared mental models.

Interdisciplinary Competency

Competencies refer to sets of behaviours that are instrumental in dealing with an underlying intent (Boyatzis, 2008). We understand interdisciplinary competencies as instrumental sets of behaviour in dealing successfully with interdisciplinary endeavours (see also Brandstädter & Sonntag, 2016). As such, interdisciplinary competencies extend teamwork competencies (Stevens & Campion, 1994) to the unique demands of interdisciplinary work settings. Bromme (2000) underlines that individual competencies need to be specific for interdisciplinarity to explain success and failure in interdisciplinary work. This specificity of interdisciplinary competencies refers to an interpretative approach of competencies (Sandberg, 2000) which emphasizes that competencies are mentally constructed by the meaning the employee makes of his or her work. With regard to interdisciplinarity, it makes use of employees' experience that interdisciplinary work is different from other teamwork. In short, interdisciplinary competencies are learned instrumental behaviours, which enable employees to deal with the specifics of working across disciplinary boarders. To a certain degree, they are expected to resemble teamwork competencies such as communication skills or collaborative problem solving (Stevens &

Campion, 1994), but essentially go beyond traditional teamwork competencies to the integrative core of interdisciplinarity.

In the past, research has dealt with selected challenges of interdisciplinary work and individual competencies to deal with them. Bromme (2000) described communication as a central challenge in interdisciplinary teams, as each person is an expert in her or his own discipline, but a layperson regarding all other disciplines. Hence, communication skills regarding expert–layperson communication influence interdisciplinary outcomes (Bromme, 2000). In addition, the cognitive challenge of integrating diverse bodies of knowledge has been discussed as being characteristic for interdisciplinarity (Steinheider et al., 2009; van Knippenberg et al., 2004). To reach the goal of innovative interdisciplinary work, it is necessary to use the entire spectrum of information distributed among team members. Thus, knowledge integration is a core task in interdisciplinary teams. Steinheider et al. (2009) consider knowledge integration an individual skill, and found it to be a central predictor for the success of interdisciplinary teams.

The first valuable attempts to integrate different challenges of interdisciplinary work into a requirement or competency model were made by Brandstädter and Sonntag (2016) and by Lattuca, Knight, and Bergom (2012). Based on a requirement analysis, Brandstädter and Sonntag (2016) proposed 40 competency dimensions which cover various traits and abilities (e.g., language adjustment, friendliness, conscientiousness). The strength of completeness in terms of a full array of useful competencies and attributes, however, comes at cost of a lack of specificity: in our view, this model also covers many general teamwork situations. On the other hand, Lattuca et al. (2012) assessed only three interdisciplinary competencies (reflective behaviour, recognizing disciplinary perspectives, and interdisciplinary skills) for learning outcomes in engineering students. Unfortunately, little information is presented regarding the generation of this model and the definitions of these dimensions, especially the

interdisciplinary skills dimension. As a consequence, the first models appear to be either extremely detailed or not detailed enough in terms of skills to provide a framework for analysing behaviours and its practical use.

To examine which competencies are specific to and relevant in interdisciplinary settings, we chose an inductive analysis of qualitative data for our first study (Study 1). This approach allowed us to use the experiences of interdisciplinary expert practitioners in defining core competencies for interdisciplinary work. In a subsequent survey (Study 2), we attempted to replicate our findings quantitatively. Finally, Study 3 served as a validation study. This mixed-method approach combines the features of qualitative and quantitative methods to identify interdisciplinary competencies (Eisenhardt & Graebner, 2007).

Study 1: Development of a Model

The goal of the first study was to inductively develop a model of interdisciplinary competencies based on a requirement analysis for interdisciplinary settings. Thus, a qualitative approach featuring in-depth interviews was chosen. This enables the grounding of model dimensions in the experiences of interdisciplinary practitioners by analysing observations of successful behaviours and deriving specific competency dimensions.

Method and Results

The development process was based on the critical incident technique (CIT, Flanagan, 1954) as a method for requirement analysis. The CIT offers a systematic approach to analyse and categorize functional behaviours in fulfilling task requirements. A critical incident includes both crucial situational demands and behaviours (Koch, Strobel, Kici, & Westhoff, 2009). The CIT includes three steps: gathering critical incidents, rating their relevance for the task, and classifying incidents into requirements (Flanagan, 1954). To gather critical incidents, in-depths interviews were conducted. Subject matter experts shared their observations of situations central for interdisciplinary cooperation, in which a person made either a very positive or negative contribution to an interdisciplinary outcome. From those

incidents, critical behaviours were derived and clustered into categories of interdisciplinarity requirements and corresponding competencies.

Sample and data collection.

The sample consists of two data sets combined. For the first dataset, we contacted organizations in industry and academia and invited people with extensive experience in interdisciplinary work to be subject matter experts for this study. In the first data collection process, ten interviews with subject matter experts were conducted. All informants (six men, four women) were highly experienced in interdisciplinary projects. Seven of them worked in academia, while three of them worked in industrial settings. Informants had diverse disciplinary backgrounds (information technology, engineering, humanities).

The interviews were conducted in September 2014; five of them were face to face and the others took place via phone. All interviews were recorded and later transcribed. During each interview, informants were asked to describe two or more different critical incidents in interdisciplinary work. To do so, they recalled situations in which someone did either a very good or a very poor job in collaborating with a colleague from a different discipline (see online supplementary files for the interview protocols). Interdisciplinary work was defined as a collaboration of people from at least two different disciplinary backgrounds. We then asked about what led to the incidents, what the acting person did, as well as which behaviours would have been effective and ineffective in the respective situations. Each interview took about 30 minutes. From each critical incident, both positive and negative behaviours (M = 4.2 behaviours per incident) were derived by the informant that clearly reflected interdisciplinary competency. In total, 101 critical behaviours were collected.

As a second data source, we used interviews using the CIT which were conducted to analyse requirements for holders of doctorates in academia and industry settings (for the interview protocol, see the online supplementary file). Invitations for participation were sent

out via email to organizations that we knew to employ STEM graduates and via social networks. We interviewed a total of 16 people with PhDs in leadership positions. This study focused on STEM fields (science, technology, engineering, mathematics). Informants worked either in industry (n = 7) or academia (n = 9). Informants reported on a variety of requirements including interdisciplinarity. For inclusion, incidents had to refer to interdisciplinary competencies[8]. We extracted 24 behaviours from the eleven incidents extracted from this second data source.

Categorization and analysis are based on both data sets combined. Thereby, 125 positive and negative behaviours were included in the following qualitative analysis. A summary of incidents and behaviours is available as an online supplementary file.

Results of interview-based data collection.

The critical incidents and key situations reported by the interviewed subject matter experts built the data basis for deduced behaviours. First, the informants themselves were asked to point out particularly helpful or harmful behaviours. Second, the first author revisited the incidents and also extracted behaviours. Finally, during a following classification workshop, behaviours were deduced by workshop participants. All this information was combined for the classification process. In the following, we describe two incidents to give an example of incidents and the subsequent procedure. In the first situation, the informant assessed the behaviour of the acting person as positively related to interdisciplinary outcomes:

> We wanted to launch a new chemical product and to do so there is quite an extensive workflow to follow. I sent [the acting person] to represent our department in the interdisciplinary team that would coordinate the product launch. The process to bring the final product on the market is

[8] The critical incidents were rated in triplets by n = 89 people using the Repertory Grid Technique. Here, raters had to compare the three incidents and describe similarities between two incidents. Whenever "interdisciplinarity" was mentioned, the incident was included in this study.

> described in great detail— 400 bullet points on the list. Then they discuss which department does what, and what might be outsourced. […]Members of that interdisciplinary team tried to pass the buck of unwanted tasks to one another. There is a lot of conflict potential. [The acting person] described well which possibilities and competencies our department has, but also what kind of expertise we don't have. Don't pass the buck, but don't monopolise either. After many hours, they organized the workflow and all tasks associated with it. (Incident 5, Informant 2)

Positive behaviours based on this were "explain own skills", "understand own limitations", "explain own limitations" and "take a fair share of tasks". The informant afterwards amended "step into other person's shoes". Negative behaviours would be "monopolise" and "pass the buck on unwanted tasks".

Some informants described situations in which a lack of interdisciplinary skills seriously hampered project success:

> This happened in a transdisciplinary project and project partners were in different locations. Part of the project was to develop a lifeline for fire fighters which should be equipped with certain sensors like gas detectors. One project partner developed the lifeline, another one the sensors. After months of separate work, all partners met and also presented their prototypes. It was like a comedy: [a project partner] said "Well, now the lifeline is way too thin for the sensors". They didn't even communicate in the month apart. After this fiasco they decided that something needed to change. And it did. They talked more often; they showed openly what they were working on, not in an abstract matter, but hands on. (Incident 12, Informant 7)

This incident added behaviours such as "meet regularly", "openly show your work" and "talk 'hands on'". In the same vein, all incidents were analysed regarding behaviours with positive or negative implications for interdisciplinary outcomes.

Classification workshop.

To condense the critical behaviours gathered in interviews, a classification workshop was held with six psychologists experienced in requirement analyses. Involving people with this background has been shown to improve categorization quality (Koch et al., 2009).

Transcripts of incidents and cards with corresponding behaviours were used as the starting point to sort and categorize. During the sorting procedure, the method of thinking

aloud (Ericsson & Simon, 1993) was employed to discuss which categories should be established and to define the differences between them. For each behaviour, participants discussed which requirement a person fulfils when engaging in this behaviour. Workshop participants developed names for categories based on included behaviours. When analysing behaviours based on critical incidents, several general competencies and behaviours commonly emerge. To ensure that specific requirements are the basis for the competency model, Flanagan (1954) suggests a relevance rating. Here, participants analysed the relevance of each category ("is this a typical requirement for interdisciplinary work?") and its uniqueness for interdisciplinarity ("is this required for any kind of teamwork or is this unique for interdisciplinary collaborations?") and collectively decided whether or not a dimension should be kept.

Results of the classification workshop.

As a result, four competencies were included in the model of interdisciplinary competencies (see Table 1). *Initiative for exchange* is defined as a proactive promotion of interdisciplinary collaboration by, for instance, making suggestions, proposing solutions, and initiating concrete discussions. In addition, the willingness to deal with additional expenses caused by interdisciplinarity is essential in this dimension. *Target group-specific communication* includes communicative behaviours, which are especially important in interdisciplinary settings, such as flexible adjustments in language for different audiences, "translating" between different disciplines, and patience in explaining. *Knowledge integration* refers to the cognitive process of combining and incorporating different disciplinary perspectives; it means an intellectual curiosity towards other disciplines, openness to others' arguments, and search for connections. *Reflection and appreciation* is a compound dimension involving reflecting on one's own disciplinary perspective and appreciation of other disciplines. Reflection on one's own disciplinary perspective includes

Table 1
Study 1: Initial Model of Interdisciplinary Competency based on Qualitative Requirement Analysis

Dimension	Behavioural Indicators	Summary of a Representative Incident
Initiative for exchange	– Making suggestions – proposing solutions – initiating concrete discussions – abstract interactions (-) – giving up (-) – waiting for others to act (-)	(-) Transdisciplinary project in distant cooperation. Goal: develop a lifeline with sensors for fire fighters. One project partner developed the lifeline, the other the sensors. After months of separate work, partners meet and show their prototypes. The lifeline was too thin to fit the sensors. Afterwards people laughed it off and decided to talk and meet more
Target group-specific communication	– Flexible adjustment to different audiences – bringing stakeholders on board – translating between disciplines – patience in explaining – communicate on different levels of abstraction (-) – force own opinion on others (-)	Although she is not a lawyer herself, the acting person likes to deal with legal texts and can also understand them in terms of content. She can then convey the contents of the legal texts to colleagues. She likes to communicate with and interpret between authorities, lawyers and colleagues.
Knowledge integration	– Search for connections – intellectual curiosity – openness to others' arguments – active integration	A mechanical engineer conducts a joint project with sociologists and economists. In the corresponding discussions between the project members, it becomes clear how differently the disciplines methodically approach a topic. The members have prejudices against the other methods: "What you do is not research, just trial and error. This is like tinkering!", says one of them. The acting person manages to open up to the arguments of the other disciplines without losing sight of her own methods. Also, others start to use some of her ideas and methods.
Reflection and appreciation	– Realizing own limits – uphold own quality criteria – accepting others' premises – taking different approaches and methods seriously – lower own standards (-) – ignore methods of own discipline (-) – consider the other as incompetent (-) – take credit for others' achievements (-)	Conference on engineering education. Interdisciplinary field with researchers from different disciplines. One presentation dealt with a study on student motivation; however, the operationalization was faulty, according to the informant. Difficult situation: how to uphold own quality criteria without to condemn procedures from other disciplines.

Note. (-) refers to a negative behavioural indicator or an incident with a negative interdisciplinary outcome. Additionally derived dimensions *cooperation skills, negotiation skills*, *networking*, *basic communication*, *meeting management*, and *professional expertise* were not included in the model due to their lacking specificity for interdisciplinarity.

behaviours such as realizing the limits of one's own discipline, upholding one's quality criteria, but also questioning one's premises. The appreciation of other disciplines includes valuing diversity and taking different approaches and methods seriously.

The final rating of relevance during the workshop resulted in the exclusion of six dimensions from the final model due to their lacking uniqueness for interdisciplinarity; that is, those behaviours are assumed to have beneficial outcomes in any kind of collaboration and are not more strongly required in interdisciplinary than in disciplinary contexts. Those dimensions were *cooperation skills* (teamwork skills, conflict management), *negotiation skills* (arguing adequately), *networking* (introducing people, building and using professional networks), *basic communication skills* (active listening and formulating ideas concisely), *management of meetings* (writing meeting protocols, prioritizing), and *professional expertise* (being skilful in one's own discipline).

Discussion of Study 1

The proposed model of interdisciplinary competency consists of four dimensions: *initiative for exchange, target group-specific communication, knowledge integration* and *reflection and appreciation* (see Table 1). The compound dimension *reflection and appreciation* was developed as such because relevant behaviours in analysed incidents coincided. As many incidents involved behaviours from more than one competency dimension, we concluded that the model dimensions are not independent, but rather a composite that creates interdisciplinary competency.

This inductively derived model resonates well with the existing literature as it shows several similarities with known challenges of interdisciplinarity. Although *initiative for interdisciplinary exchange* does not have an immediate counterpart in previous research, we see a conceptual overlap with "personal commitment" from the extensive model by Brandstädter and Sonntag (2016). *Target group-specific communication* was mentioned in several interviews as being difficult ("…the entire topic of communicational barriers. That is

especially true for certain wordings. Well, there are a lot of different problems in communication." –Informant 3) and reflects the core challenge of communication across disciplinary borders (Bromme, 2000), which can be explained by common ground theory (Clark, 1996). In the same vein, the importance of understanding different disciplinary perspectives and their view on a common research question or object of interest, that is, *knowledge integration*, has been highlighted before (Steinheider et al., 2009). It can also be compared to the elaboration of distributed knowledge, as considered by van Knippenberg et al. (2004). *Reflection and appreciation* were described as relevant personal prerequisites by our subject matter experts ("In some areas you cannot say that an employee earned the company a certain amount of money, because they were involved in a project. So appreciation is a constant topic for us. And I try to be creative in appreciating, looking at the entire process, see it as a holistic process" –Informant 6). A qualitative collection of experiences with interdisciplinary projects by Epstein (2005) also outlines appreciation as a personal competency for interdisciplinary work, while Lattuca et al. (2012) elaborate on the significance of reflecting on disciplinary perspectives for interdisciplinary endeavours. Nevertheless, our qualitative data showed no indication of a special role of meta-cognition, which has been shown before to be relevant for enabling individuals to quickly connect information from different disciplines (Bunderson, 2003).

Clearly, strengths and limitations of an inductive approach to developing the model have to be weighed. In our sample, informants from academic settings were overrepresented. This might have biased the results in a way that situations typical for research projects have been favoured over typical situations in industry settings. However, in the classification workshop, behaviours derived from interviews with informants in industry were earmarked. These behaviours did not cluster but were spread evenly over all dimensions. Hence, there is no reason to believe that the sample composition biased the results. Clearly, the classification of incidents and behaviours into competency requirements can be a rather subjective

procedure. However, close adherence to qualitative data keeps this theory building well justified (Eisenhardt & Graebner, 2007). In our case, the classification of behaviours into competency dimensions was done by a single workshop group. Although we implemented recommendations by Koch et al. (2009) in the classification process (e.g., method of thinking aloud, experienced participants) to increase objectivity and reliability, we cannot guarantee that a second workshop group would have arrived at a completely identical competency model. The chosen approach is clearly limited as it does not allow studying inter-rater reliability. Nevertheless, the results' credibility is increased by the fact that the proposed competency dimensions have been discussed in the literature before, although not with this specific composition and context. Furthermore, the subsequent studies will test the validity of the model results to improve upon limitations of the classification approach.

In sum, this qualitative study provides insight into competency requirements in interdisciplinary collaborations. The developed model is parsimonious, unique for interdisciplinary collaborations, and integrates various challenges linked to interdisciplinarity. As a result, this study provides a model for interdisciplinary competencies that can be deductively tested.

Study 2: First Quantitative Test of the Competency Model

Our goal for the second study was threefold. First, we wanted to test the conceptual dimensions of the model in a quantitative study with a larger sample to ensure that the model dimensions actually mirror the appropriate scope of individual experiences in interdisciplinary collaborations. Second, we wanted to develop a scale to address the experiences of employees in interdisciplinary collaborations focusing on self-reported interdisciplinary competencies. Third, as a first validation of the model, we analysed convergent validity with regard to motivation for interdisciplinary work and considered the influence of experience and significance of interdisciplinarity for the job tasks on self-reported interdisciplinary

competencies (i.e., *initiative for exchange*, *target group-specific communication*, *knowledge integration* and *reflection and appreciation*).

For a first test of convergent validity, we analysed the relation between the connected yet independent variables of interest in interdisciplinary work and competencies. Motivation in general, and interest in particular, is beneficial for competency development (Krapp, 2002). Additionally, there is evidence that perceived proficiency generates greater interest in a field or activity (Bandura & Schunk, 1981). Analyses of convergent validity should demonstrate this positive relationship between interdisciplinary competencies and interest.

H1: Interdisciplinary competencies are positively related to interest in interdisciplinary work.

Furthermore, based on theories of competency development (Ley, Lindstaedt, & Albert, 2005), we consider workplace experience with interdisciplinarity relevant. Long-lasting experience in interdisciplinary teamwork should be related to more incidents for learning and competency development and as such lead to an increase in interdisciplinary competencies. In the same vein, van Knippenberg et al. (2004) emphasize that collaborators need time to develop competencies to elaborate divergent perspectives. Cummings and Kiesler (2008) have shown that previous experience with a particular colleague improves engagement in interdisciplinary projects with this person and as a consequence project outcomes. Similarly, we suggest that previous experience with interdisciplinary projects would enhance relevant competencies. At the same time, people with interdisciplinary competencies might be more strongly attracted to jobs with requirements for a high degree of interdisciplinary collaboration. In addition, we propose the significance of interdisciplinarity for the current job to be relevant. The more the job depends on interdisciplinary collaboration, the more resources should be invested into making interdisciplinary collaboration work. Consequently, in settings of high dependency on interdisciplinarity, more opportunities for competency development emerge, leading to higher competency levels.

H2: Experience in interdisciplinary work is positively related to interdisciplinary competencies.

H3: Significance of interdisciplinarity for the job is positively related to interdisciplinary competencies.

Method

To test the proposed model of interdisciplinary competencies and our hypotheses, we conducted an online survey among employees with experience in interdisciplinary work.

Item development.

Based on the previously developed model of interdisciplinary competencies, the authors formulated items for each dimension. The wording focused on competencies and thus included phrases such as "I can easily" or "I'm good at". We developed items for each model dimension: *initiative for exchange* ("It is easy for me to take the initiative in an interdisciplinary meeting"), *target group-specific communication* ("In interdisciplinary teams, it is difficult for me to avoid unnecessary technical terms"), *knowledge integration* ("In interdisciplinary work, I am good at connecting and integrating knowledge from different disciplines") and *reflection and appreciation* ("I can very precisely name the problems my discipline deals with and where differences from other disciplines lie").

To check face validity, items were randomized and allocated to the model dimensions by four senior scientists and student assistants familiar with the model of interdisciplinary competency. Mismatched items were either revised to better represent only one dimension or excluded. The item development process resulted in a pool of 66 items for four model dimensions. Items were rated on a 6-point scale. Regarding convergent validity, we drafted four items on interest in interdisciplinary work; that is; whether one enjoys working in an interdisciplinary team ("The possibility to work interdisciplinarily contributes to my work satisfaction", "I want to do more interdisciplinary work", "The possibility to do interdisciplinary work inspires me", "It tempts me to work with people from other disciplines

that have a completely different approach to things than I have"). Experience in interdisciplinary work was reported in years. Significance of interdisciplinarity for the job was measured with a single item ("How significant is interdisciplinary cooperation for your job?") on a 5-point rating scale (1 = *unimportant*; 5 = *very important*).

Sample.

To recruit participants for the online questionnaire study, employees of organizations with an interdisciplinary focus and researchers with a history of interdisciplinary work (based on website information of employing organizations and research funding agencies) were invited via email to participate in the survey. We looked for organizations working in sustainability, biomedicine, bioengineering, and human-machine-interaction, because these fields are known for their interdisciplinarity. The recruiting process resulted in a convenience sample of 315 employees (55.3 % women) who work interdisciplinarily. Participants were between 22 and 68 years old (M = 36.81; SD = 9.33) and had on average eight years of experience in interdisciplinary work (M = 7.92 years; SD = 7.17). Most participants (84.5%) currently worked in academia and 98.4% of participants had completed further education and thus had been socialized in an academic discipline (59.9% humanities and social sciences, 21.5% in engineering, 12.7% in natural sciences, 5.9% life sciences). Most participants (75.8%) worked at least weekly with people from other disciplines (38.5% daily interdisciplinary work). A subsample of 202 people (64.1 %) completed the survey on a second occasion, with a retest interval of approximately two weeks.

Analytical approach.

At the beginning, items were selected based on descriptive item analysis, factorial approaches and considerations of item content to reduce the overall number of items. Based on the results of the qualitative study, in which behaviours associated with different competency dimensions occurred in similar situations, we did not expect statistical independence of model dimensions. We employed exploratory structural equation modelling

(ESEM; Asparouhov & Muthén, 2009), which combines features of exploratory factor analysis and confirmatory factor analysis (CFA). ESEM enables the testing of models with item cross-loadings and should fit the hypothesized structure better than CFA models. CFA is based on independent cluster models (ICM-CFA) and thus poses overly strict assumptions regarding zero cross-loadings. This assumption may lead to a poor model fit for many psychological constructs, which often have slightly correlated factor structures, such as the Big Five personality factor structure (Marsh et al., 2009).

To obtain information on measurement generalizability, we conducted tests of measurement invariance over the retest interval. Using the data from the subsample of 202 people who took the survey a second time, we applied the taxonomy for longitudinal measurement invariance by Marsh et al. (2009). It implies a comparison of increasingly restricted models between time points, from weak to complete measurement invariance.

Finally, to test our hypotheses, interest in interdisciplinary work was correlated with the competency dimensions as an indicator for convergent validity (H1). Also, years of interdisciplinary experience (H2) and significance of interdisciplinarity for the current job (H3) were linked to the model dimensions in a regression model.

Results

The following analyses are based on a sample of 315 people from the first part of the study. Analyses based on the subsample of 202 people who took part in a repeated measurement are labelled accordingly.

As a first step, we combined different analytical methods to reduce the number of items yielding three to four items per dimension. Based on descriptive item analysis, only a few items were excluded: four items due to low item difficulty ($P_i < 0.85$) and one item due to little variance. Both low item difficulty and little variance confine the information that can be gathered from an item: if nearly all participants fully agree with an item, little information about the interdisciplinary competencies of an individual can be inferred. The remaining 61

items for the competency dimensions as well as the four interest items were screened in an iterative process: factorial analyses with five factors (that is, four for the hypothesized model dimensions and an additional interest factor) were the starting point (see online supplementary table). We then removed items with inconclusive factor loadings and very high cross-loadings step by step. In addition to repeated statistical analyses with a decreasing item set, we considered whether the remaining items covered the content of the dimensions appropriately. This process yielded an item set of 13 competency items (Table 2).

The ESEM model based on these 13 items as well as four items on interest in interdisciplinary work and a 5-factor structure reveals that the factor loadings do not fully represent the hypothesized pattern. Items intended to represent the dimension *reflection and appreciation* of the qualitative model load on two separate factors. Some items form a pure "reflection" factor. The two items measuring the appreciation of interdisciplinary work load on the same factor as the interest items and thus create a common factor of interest and appreciation. This pattern was similarly observed in all previous analyses we did. As a consequence, we decided to drop this factor; thus, all further analyses are based on the four factor version only, including competency factors but excluding the "interest and appreciation" factor (see Table 2).

The ICM-CFA model with the remaining 13 items fits the proposed data structure quite well ($\chi^2 = 91.72$; $df = 59$; CFI = .937; TLI = .956; RMSEA = .042; SRMR = .043; see Table 2). However, correlations of the latent factors are relatively large, with *r*s between .37 and .72 (median = .52). In comparison, the corresponding ESEM model with 13 items fits the data better ($\chi^2 = 39.82$; $df = 32$; CFI = .992; TLI = .981; RMSEA = .028; SRMR = .021). The factor correlations of the latent ESEM factors based on standard geomin rotation are lower, with a median *r* of .37 (*r*s between .26 and .52).

Table 2

Study 2: Factor Loadings of the Confirmatory Factor Analysis and Descriptive Item Statistics of Manifest Variables for the Final Item Set

No.	Item text	Factor loading	*M*	*SD*
Initiative for exchange				
01	It is easy for me to make specific suggestions in order to create a basis for discussion in an interdisciplinary team.	.77***	3.48	1.06
02 [a]	Often, I am the person who has the ideas for interdisciplinary projects.	.58***	2.82	1.32
03	It is easy for me to take the initiative in an interdisciplinary meeting.	.58***	3.16	1.31
Target group-specific communication				
04 [a]	In interdisciplinary teams, it is difficult for me to avoid unnecessary technical terms.	.41***	3.10	1.21
05	In interdisciplinary teams, I find it difficult to get my point across.	.68***	3.63	1.02
06	It is not a problem for me to adapt my language so everyone in an interdisciplinary team understands.	.61***	3.64	1.10
07	Regarding language, I find it hard to engage with team members from different disciplinary backgrounds.	.50***	3.71	1.14
Knowledge integration				
08 [a]	In interdisciplinary work, I am good at connecting and integrating knowledge from different disciplines.	.82***	3.90	.89
09	In interdisciplinary teams, I succeed in connecting different disciplines content-wise.	.75***	3.89	.85
10	In interdisciplinary teams, I can easily comprehend what other members work on with regards to content.	.57***	3.51	.86
Reflection				
11	I uphold the quality criteria of my own discipline in interdisciplinary teams.	.48***	3.93	.91
12	I can very precisely name the questions my discipline is in charge of and how my discipline differs from others.	.80***	3.83	1.02
13 [a]	I can very precisely name the methodological and content-related features of my discipline.	.75***	3.93	.97

Notes. N = 315; Factor loadings show loading of the manifest variable on the latent variable of each dimension; standardized coefficient; Model fit of CFA: Chi²-test of model fit: 91.72, *df* = 59, *p* = .004; RMSEA = .042; CFI = .967; TLI = .956; SRMR = .043.
6-point rating scale from 0 to 5; [a] = item was used as reference item for the ESEM-within-CFA approach.

This result indicates that the less restrictive ESEM model is more suitable for the underlying data structure with slightly correlated latent factors. Thus, we built our further analyses on the geomin-rotated ESEM model (see Table 3).

We tested measurement invariance over the two-week retest interval. Results suggest strong, although not strict, measurement invariance over time (χ^2 = 289.53; *df* = 213; CFI = .969; TLI = .952; RMSEA = .034; SRMR = .062). Therefore, factor loadings, uniquenesses,

Table 3

Study 2: Geomin Rotated Factor Solution of ESEM Model with Final Itemset

Item no.	F1: Initiative for exchange	F2: Target communication	F3: Knowledge integration	F4: Reflection
01	**.57****	-.03	.25	.04
02[a]	**.71****	.03	-.04	.01
03	**.41****	.11	**.35****	-.14*
04[a]	-.21	**.65****	.01	-.05
05	-.13	**.49****	.10	.04
06	.11	**.49****	.06	.02
07	.03	**.54****	-.11	.13
08[a]	.05	-.04	**.82****	.01
09	-.02	.02	**.71****	.05
10	-.02	.09	**.52****	.05
11	-.02	.05	-.01	**.48****
12	.03	-.01	.06	**.74****
13[a]	-.01	.02	.01	**.76****

Notes. Standardized coefficients. Model fit: Chi²-test of model fit: 45.38, *df* = 32, *p* = .06; RMSEA = .036; CFI = .987; TLI = .968; SRMR = .022.

F = factor loadings for each factor.

***p* < .01; **p* < .05; [a] item was used as reference item for the ESEM-within-CFA approach

factor variance–covariances and intercepts can be compared at both time points. Whenever the more parsimonious model (i.e., containing more constraints) was compared with the less parsimonious model, fit indices revealed only slight deteriorations in fit (ΔRMSEA < .015; ΔCFI and ΔTLI <.10). In many cases, adding constraints actually improved fit according to indices that control for parsimony (RMSEA, TLI). The short-term retest correlations based on latent factors range from .70 to .92 and thus speak in favour of short-term stability.

As ESEM requires all factors to be simultaneously related or unrelated to external variables, we converted the ESEM model into a CFA model for further analyses according to the ESEM-within-CFA approach (Morin, Marsh, & Nagengast, 2013). To test convergent

Table 4

Study 2: Correlation of Study Variables

	Measure	1.	2.	3.	4.	5.	6.	7.
1.	Initiative for exchange	.66	.58***	.75***	.38***	.55***	.35***	.40***
2.	Target group-specific communication	.33**	.64	.53***	.37***	.34***	.34***	.15*
3.	Knowledge integration	.53**	.35**	.75	.53***	.34***	.40***	.26***
4.	Reflection	.24**	.24**	.40**	.71	.21**	.07	.17**
5.	Interest in interdisciplinary work	.37**	.23**	.48**	.16**	.78	.46***	.24***
6.	Significance	.29**	.27**	.36**	.06	.38**	-	.18***
7.	Experience in years	.34**	.10	.22**	.13*	.17**	.18**	-
	M	4.15	4.52	4.76	4.89	4.80	4.49	7.92
	SD	.95	.78	.71	.77	.88	.75	7.17

Notes. N = 315, table shows correlations between manifest variables; are shown below the diagonal and correlations between latent variables according to the CFA-model are shown above the diagonal. Cronbach's alpha is shown in the diagonal.

*p < .05; ** p < .01.

validity as described in H1, we correlated a latent variable of interest in interdisciplinarity and the latent factors of interdisciplinary competencies. Correlation coefficients are significant and vary for the competency dimensions *initiative for exchange* (.23), *target group-specific communication* (.17), *knowledge integration* (.40) and *reflection* (.11). Table 4 shows correlations between all constructs for Study 2.

To test Hypotheses 2 and 3, we estimated the influence of experience in interdisciplinary work and the significance of interdisciplinary cooperation for the current job on self-reported competencies using path analysis, as shown in Figure 1. Each year of experience in interdisciplinary work is associated with slight increases in *initiative for exchange, knowledge integration* and *reflection* (H2). The significance of interdisciplinary cooperation for the job is positively related to *initiative for exchange, target group-specific communication* and *knowledge integration* (H3). We also included interest in the model depicted in Figure 1. Please note, however, that in the regression model the path between interest and target group-specific communication is not statistically significant.

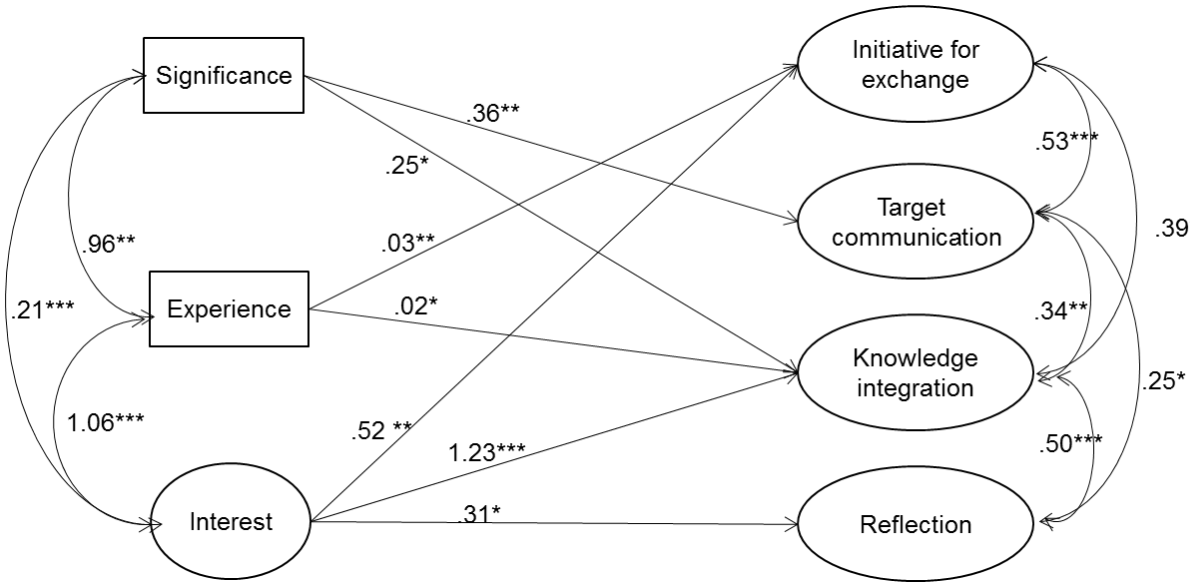

Figure 1. Study 2: Path diagram of influencing factors (significance of interdisciplinarity for the job, experience in years, and interest in interdisciplinary work) and interdisciplinary competencies. Unstandardized coefficients. Model fit: $\chi^2 = 133.77$; df = 106; CFI = .983; TLI = .972; RMSEA = .029; SRMR = .030

Discussion of Study 2

We applied the model of interdisciplinary competencies in a survey among employees with experience in interdisciplinary work to test its dimensions. We were able to replicate the findings of the previous qualitative study, in which the dimensions *initiative for exchange*, *target group-specific communication,* and *knowledge integration* were extracted. However, the quantitative data show a different pattern than expected regarding *reflection and appreciation*. In the qualitative interviews, incidents with behaviours linked to those dimensions included both dimensions, thus leading us to believe them to be a compound characteristic of interdisciplinary competencies. As the quantitative data did not support this hypothesis, we focused on the competency of *reflection*, representing awareness of one's own disciplinary perspectives. The other part of the compound competency, appreciation, merged into a common factor with interest. Taking item content overlap into account, we understood that appreciation and interest share a common motivational underpinning. We concluded that appreciation of other disciplines is an attitudinal prerequisite for interdisciplinary work that

might ease collaboration. This motivational perspective on appreciation fits less well with our understanding of competencies as capabilities (Boyatzis, 2008). Consequently, we decided to remove appreciation from the compound dimension and to focus on *reflection* instead.

Next, we tested our items designed to measure interdisciplinary competencies for measurement invariance. Strong measurement invariance was found for the repeated measure. These analyses indicated that item intercepts as well as factor loadings are invariant over time and latent means can appropriately be compared. Please note that we, in fact, found substantial retest stability over a short-term interval.

For the purpose of construct validation, we considered the association between competencies and interest. Interest can be seen as a prerequisite for engaging in interdisciplinary work and developing interdisciplinary competencies. We observed low to moderate correlations with *initiative for exchange*, *knowledge integration* and *reflection*. However, there was no significant relationship between *target group-specific communication* and interest, suggesting that an interest in engaging in interdisciplinary work can be independent from required communication competencies.

Path analysis showed that experience in interdisciplinary work and significance of interdisciplinarity for the job had specific effects on the model dimensions. Each year of experience in interdisciplinary work increases a person's *initiative* in interdisciplinary settings and their *reflection* on their own disciplinary perspective. This result provides a first impression of competency development in interdisciplinary work environments on the job. The main predictor of self-reported interdisciplinary competencies was the significance of interdisciplinary cooperation for the job. The more relevant the collaboration with other disciplines was to fulfilling job requirements and tasks, the higher the self-reported competencies. However, high relevance was not associated with *reflection*, a competency dimension that is less task-oriented than the others.

This study was a first test of the model of interdisciplinary competencies. As such, it also has certain limitations. Employees working in academia were overrepresented in our sample. We do assume that interdisciplinary collaborations are associated with certain requirements – which stem from the collaboration of people with different disciplinary backgrounds and perspectives. It is the multitude of perspectives that makes interdisciplinary work complicated, and we assume that this effect is independent from the particular sector or industry. Nevertheless, in academia, disciplinary identities might be more apparent, as most academic organizations are clearly organized according to disciplinarity, while this is not necessarily the case for organizations outside of academia. Thus, this study's implications might be limited to the academic work environment and clearly defined disciplines. A second limitation concerns the use of a single item measuring the significance of interdisciplinarity for the work task. All items are prone to potential misunderstandings based on wording; however, with single items this cannot be remedied by averaging.

We could clearly confirm the proposed model of interdisciplinary competencies in a sample of experienced practitioners. As a consequence, the findings support the qualitative approach featured in Study 1 and compensate some limitations of the previous study. In addition, the study revealed experience and significance of interdisciplinary cooperation as relevant predictors of self-reported interdisciplinary competencies.

Study 3: Further Model Validation

In the third study, we continued to validate the model. One goal was to replicate the findings of Study 2 and show that the developed model generalized in a more diverse sample. The second goal was to study the relationship between interdisciplinary competencies and related concepts for convergent validation. The third goal was to show that interdisciplinary competencies are predictive for interdisciplinary team outcomes above and beyond general teamwork competencies.

In our samples in both Study 1 and Study 2, employees working in academia were overrepresented. Although we assume that the mechanisms of interdisciplinary work are similar between industry and academia, we wanted to show that the interdisciplinary competency model developed works well in teams outside of academia, too.

To further validate the model, the relationship between interdisciplinary competencies and other constructs should be studied. We expect interdisciplinary competencies to be positively related to a general preference for teamwork and self-efficacy for teamwork, as well as interest in interdisciplinary work (a link we have seen in Study 2). Interest, self-efficacy beliefs and competency development are closely linked (Bandura, 1994): positive experiences with interdisciplinarity strengthen both interest and self-efficacy beliefs, which in turn foster competency development. Interest, self-efficacy, and a preference for teamwork are motivational prerequisites for the effort of developing interdisciplinary competencies and to grapple intensely with other disciplines. With regard to the organizational circumstances of interdisciplinary work, we assume that managerial support for interdisciplinary work and high task interdependence help create surroundings in which interdisciplinary competencies can be developed. Supportive managers are aware of the requirements of interdisciplinary work and are more likely to provide the necessary resources for interdisciplinary interactions such as more time and the opportunity to reflect on the challenges of interdisciplinary work which are beneficial for the development of interdisciplinary competencies. High task interdependence forces peers to work closely together to accomplish their work tasks. Here we assume an increased motivation to make interdisciplinarity work by developing interdisciplinary competencies.

H1a: Interdisciplinary competencies are positively related to interest in interdisciplinary work, preference for teamwork and self-efficacy.

H1b: Interdisciplinary competencies are positively related to managerial support for interdisciplinary work and task interdependence.

H2: Interdisciplinary competencies predict outcomes of interdisciplinary teamwork above and beyond general teamwork competencies.

Method

Study 3 was an online study with a sample of dyads of employees who work interdisciplinarily. To improve generalizability of the developed model, we aimed at including more non-academic participants in the sample.

Sample.

This sample has a dyadic structure. We recruited N = 448 participants (57.6% women) with experience in interdisciplinary work as target persons and had them invite a colleague with a different disciplinary background for a peer rating. This resulted in a sample of n = 153 dyads. To recruit target persons with non-academic backgrounds, we contacted interdisciplinary health care clinics, centres for social paediatrics, theatres, museums, and environmental agencies. Target persons were on average 41.96 years old (SD = 11.46; peers: M = 38.70; SD = 10.55) and 85.9% had a university degree (7.6% humanities, 40.1% economics and social sciences, 10.8% natural sciences, 18.6% medicine and health, 10.6% engineering). Most participants (91.5%) without a degree had completed an apprenticeship (e.g., nursing, physical therapist). Most common occupations among target persons were social workers (n = 55), physicians (n = 53), psychologists (n = 44), nurses (n = 12), theatre dramatic advisers (n = 8), and museum curators (n = 7). Only 28.8% of target persons worked in academia. Among the peers (74.3% women), 80.4% had a university degree (4.9% humanities, 39.8% economics and social sciences, 7.3% natural sciences, 27.6% medicine and health, 12.2% engineering).

The relationship between the target person and the corresponding peer was characterized as being colleagues by 60.8% and project partners by 18.3%. In 9.8% of cases, subordinates answered the peer survey. In 2.0% of cases, the peer was the superior of the target person. We tested whether target persons who obtained a peer report and those who did

not differed from each other regarding demographics and self-reported interdisciplinary competencies. Target persons with a peer report had significantly more often received a university degree ($\chi^2(1) = 10.66$; $p < .001$) and rated their knowledge integration competency higher than target persons who did not obtain a peer report ($t(445) = 2.11$; $p < .05$).

Instruments.

Instruments for target persons and peers differed. Target persons were given a more extensive survey. All items were rated on a 6-point rating scale.

Target person's questionnaire. Interdisciplinary competencies were measured using the 13 item scale developed in Study 2 (see Table 2). For general teamwork competencies, the Teamwork Competency Instrument by Halfhill and Nielsen (2007) was used. We included the subscales conflict resolution, collaborative problem solving, communication, goal setting and performance management, planning and task coordination, and meeting management skills with three items each. An example would be "I help establish specific, challenging, and accepted team goals" (subscale goal setting and performance management).

In addition, we included two groups of convergent measures: (a) motivational attitudes toward teamwork (interest, self-efficacy, and preference for teamwork) and (b) organizational aspects of interdisciplinary work. Interest in interdisciplinary work was measured with the same four items as in Study 2 (e.g., "The possibility to do interdisciplinary work inspires me"). Self-efficacy for teamwork was measured with three items from the scale by Eby and Dobbins (1997), e.g., "I can work very effectively in a group setting". We included three items from the subscale Preference for Teamwork from the Workgroups Characteristics Measure (Campion, Medsker, & Higgs, 1993) in the original wording (e.g., "I generally prefer to work as part of a team"). Regarding organizational aspects, we adapted items from the Workgroups Characteristics Measure (Campion et al., 1993) to fit to interdisciplinary work (changes are marked in italics): managerial support for interdisciplinary work (e.g., "Higher management in my organization supports the concept of *interdisciplinary* teams") and task

interdependence (e.g., "I cannot accomplish my task without information or materials from other team members *from a different discipline*") which were measured by three items each.

As outcomes we included measures of team effectiveness and satisfaction with the team and adapted them to better fit to interdisciplinary teamwork. Team effectiveness was measured by four items originally from Maynard, Mathieu, Rapp, and Gilson (2012). A sample item is "How effective was your team in making use of the skills of the different team members *and disciplines*?". Here, we added "and disciplines". Team satisfaction was measured by three items from Hertel, Konradt, and Orlikowski (2004), e.g., "I am satisfied with the team climate among the *interdisciplinary* members of the team".

***Peer questionnaire*.** The peer questionnaire only included demographics and outcome measures: four items of Team Effectiveness (Maynard et al., 2012) and three items for Team Satisfaction (Hertel et al., 2004).

Analytical approach.

First, to replicate the factor structure found in Study 2, we used confirmatory factor analysis. Second, we tested convergent validity according to Hypotheses 1a and 1b using structural equation modelling with latent variables. Third, we compared interdisciplinary competencies with general team competencies in predicting team outcomes. As the sample size of the peer sample is relatively small, latent variables were transformed into manifest factor scores which were used for the regression models. In small samples, complex models with latent variables cannot be estimated, but using factor scores makes this possible (Devlieger & Rosseel, 2017). This leads, however, to the model being saturated; thus, the fit indices cannot be interpreted.

Results

We applied the ESEM and CFA analyses from the second study to the new sample to replicate the findings. For these analyses, we used the larger sample of all target persons (N = 447).We were able to fully replicate the results with a well-fitting CFA model ($\chi^2 = 93.68$; *df*

= 59; CFI = .973; TLI = .965; RMSEA = .036; SRMR = .041), although it did not fit as well as the replicated ESEM model (χ^2 = 30.37; *df* = 32; CFI = 1.000; TLI = 1.003; RMSEA = .000; SRMR = .016). Once again, latent factor correlations were smaller in the ESEM (*r*s from .20 to .70; median *r* = .38) than in the CFA model (*r*s between .26 and .74; median *r* = .41). To replicate the ESEM model estimated in Study 2, we applied the ESEM-within-CFA approach (Morin et al., 2013).

To test Hypothesis 1a, we correlated latent factors of interdisciplinary competencies and interest, preference for teamwork, and self-efficacy for teamwork. The model fit well (χ^2 = 278.57; *df* = 161; CFI = .96; TLI = .95; RMSEA = .04; SRMR = .04). We found significant medium to high correlations between the interdisciplinary competencies *initiative for exchange*, *target group-specific communication*, and *knowledge integration* with interest, preference for teamwork and teamwork self-efficacy (see Table 5). For *reflection*, however, only the correlation with self-efficacy for teamwork was significant (*r* = .36; *p* < .001).

Likewise, we tested the correlations between the interdisciplinary competency dimensions (latent variables) and the environmental variables of managerial support and task interdependence (Hypothesis 1b, see Table 5). The model fit well (χ^2 = 188.81; *df* = 110; CFI = .97; TLI = .95; RMSEA = .04; SRMR = .04). Managerial support for interdisciplinarity was significantly associated with *target group-specific communication* (*r* = .23; *p* < .001) and *knowledge integration* (*r* = .19; *p* < .01). Task interdependence is significantly correlated with *initiative for exchange* (*r* = .33; *p* < .01), *target group-specific communication* (*r* = .15; *p* < .05), *knowledge integration* (*r* = .27; *p* < .001), and *reflection* (*r* = .18; *p* < .01). A complete correlation table is available as an online supplement.

The following analyses were carried out in the combined sample of target persons and peers (*n* = 153). We calculated factor scores using CFA modelling for each construct (interdisciplinary competencies, team competencies, outcomes). All fit indices met the criteria of a good fitting model. In a first step, we modelled the general team competencies as

Table 5

Study 3: Correlations between Interdisciplinary Competencies and Convergent Measures

Interdisciplinary Competencies	Interest in interdisciplinary work	Preference for teamwork	Teamwork self-efficacy	Managerial Support	Task Inter-dependence
Initiative for exchange	.42***	.27***	.64***	.07	.33***
Target group-specific communication	.35***	.22***	.36***	.23***	.15*
Knowledge integration	.56***	.19**	.64***	.19**	.27***
Reflection	.12	.09	.36***	.06	.18**

Notes. N = 447; correlations between latent variables according to the ESEM-model. Standardized coefficients. Model fit for model with interest, preference and self-efficacy: Chi²-test of model fit: 278.57, *df* = 161, *p* = .00; RMSEA = .040; CFI = .964; TLI = .949; SRMR = .038. Model fit for model with managerial support and interdependence: Chi²-test of model fit: 188.81; *df* = 110; CFI = .97; TLI = .95; RMSEA = .04; SRMR = .04

*$p < .05$; ** $p < .01$; *** $p < .001$.

predictors for team effectiveness and team satisfaction (self- and peer-report). The self-reported team competencies (conflict resolution, collaboration, communication, goal setting, planning, meeting management) together explained 13.9% of the variance (R^2) of self-reported team effectiveness ($p < .001$) and 7.2% of the peer-reported team effectiveness ($p = .08$; see Table 6). With regard to team satisfaction, general team competencies accounted for 7% of self-reported team satisfaction ($p < .01$) and 8.4% of the team satisfaction of peers ($p = .06$). Self- and peer-reported outcomes were positively correlated with team effectiveness ($r = .23$; $p < .05$) and team satisfaction ($r = .33$; $p < .001$). In a second step, we included interdisciplinary competencies as additional predictors. The inclusion of interdisciplinary competencies increased the R^2 of team effectiveness to .21 ($p < .001$; self-report) and .14 ($p < .01$; peer-report), respectively. The explained variance in satisfaction with the team increased to 17.0% ($p < .001$; self-report) and 12.3% ($p < .05$; peer-report). Hence, interdisciplinary competencies predicted team outcomes above and beyond general team competencies.

Table 6

Study 3: Regression of General Team Competencies and Interdisciplinary Competencies on Team Effectiveness and Team Satisfaction

Predictors	Effectiveness		Team Satisfaction of	
	Self-rated	Peer-rated	Target person	Peer
Model 1				
General team competencies				
Conflict resolution	.17	.63	.18	.24
Collaborative problem solving	-.62	-.81	-1.04	-.07
Communication	.29	1.20	1.17*	.38
Goal setting and performance management	1.28	1.15	1.40	.58
Planning and task coordination	-.76	.66	.16	-.16
Meeting management skills	.08	-2.24	-1.32	-.60
Total R^2	.14***	.07	.07**	.08
Model 2				
General team competencies				
Conflict resolution	.23	.58	.26	.32
Collaborative problem solving	-.71	-.63	-1.22*	-.26
Communication	.24	1.03	1.04*	.39
Goal setting and performance management	1.26	.91	1.44	.78
Planning and task coordination	-.70	.62	.14	-.25
Meeting management skills	-.03	-2.13	-1.26	-.65
Interdisciplinary competencies				
Initiative for exchange	.04	.11	.01	.03
Target group-specific communication	.13**	.05	.24***	.15
Knowledge integration	.15**	.22*	.21***	.08
Reflection	.09	-.10	-.06	-.08
Total R^2	.21***	.14*	.17***	.12*
Δ R^2	.06***	.05	.10***	.03

Notes. Standardized regression weights based on factor scores. *p < .05; ** p < .01; *** p < .001.

Discussion of Study 3

In Study 3, we applied the model developed in the previous studies in a new sample and replicated the statistical model of interdisciplinary competency dimensions *initiative for exchange*, *target group-specific communication*, *knowledge integration*, and *reflection*. In addition, we were able to show convergent validity. Interdisciplinary competencies were

related to the following constructs: interest in interdisciplinary work, teamwork self-efficacy, and a general preference for teamwork. These three constructs can be understood as motivational and attitudinal prerequisites of successful interdisciplinary collaborations (Bandura, 1994). In particular, it is assumed that these motivational constructs are an indicator for the effort one invests in developing interdisciplinary competencies. Furthermore, interdisciplinary competencies were related to organizational aspects of interdisciplinary work. There were small to moderate correlations between task interdependence and all four competency dimensions: The more a person depends in her or his own work on information from interdisciplinary colleagues, the higher this person rates her or his interdisciplinary competencies. This indicates that competencies might develop as a necessity to cope with interdisciplinary requirements. Managerial support was associated with higher self-reports of target group-specific communication and knowledge integration.

An important goal we pursued with Study 3 was to demonstrate the generalizability of the model of interdisciplinary competencies. Most importantly, we wanted to demonstrate that interdisciplinary competencies are different from general teamwork competencies. Interdisciplinary work most often is teamwork; however, it is a very particular kind of teamwork with unique challenges and requirements. Hence, we argue that successful interdisciplinary work requires (additional) competencies different from general teamwork competencies. General teamwork competencies as a group predicted self-reported team effectiveness and the team satisfaction of the target person albeit only communication skills were a significant single predictor. They were not, however, able to explain a colleague's team satisfaction or team effectiveness rated by peers. Including interdisciplinary competencies in the prediction model improved explained variance. This change was significant for the self-report measures. Although *initiative for exchange* and *reflection* were not significant as single predictors, the combined interdisciplinary competencies explained team effectiveness and satisfaction with the team above and beyond general team

competencies. Our results suggest *knowledge integration* and *target-group specific communication* to be core competencies for interdisciplinarity. The capability to successfully interact and integrate between disciplines has shown to be associated with self-rated team satisfaction and self- and peer-rated team effectiveness. The amount of variance explained in the outcomes by the predictors was, however, rather low.

Team satisfaction can be explained by various aspects from team culture to traits of the target person and colleagues. Participants worked in different settings of interdisciplinarity. We sampled dyads; however, some of the dyads were part of a bigger team. Here, team satisfaction is most likely explained by traits and competencies of more than one colleague, which could explain the lacking effects of competencies for the colleague's team satisfaction. Higher associations between self-reported competencies and self-reported outcomes can be explained by same source bias and are not surprising (Lindell & Whitney, 2001). It should also be noted that relatively low correlations among the outcomes in self- and peer-reports correspond with meta-analytical findings of self- and other-reports (Heidemeier & Moser, 2009).

Another important study aim was to tackle generalizability by targeting a sample outside of academia. Many participants worked in the health sector and provided care in interdisciplinary teams. Another group of participants came from the cultural sector and worked interdisciplinarily in theatres and museums. Whenever different disciplines come together to work together, interdisciplinary competencies are required. The converging evidence in support of the model from the previous study, in which academics were overrepresented, shows that the requirements are comparable for different industries or sectors.

A clear strength of Study 3 is the use of peer reports in addition to the target persons' self-reports. This avoids the pitfalls of common method variance and improves the credibility of the results. Nevertheless, we need to acknowledge that only about a third of the sampled

target persons obtained a peer report. From responses of reminders sent out to target persons, we learned that most target persons were willing to ask a colleague but not all of them were successful. We found that those who received a peer-report self-rated their knowledge integration competencies higher than those who did not obtain a peer-report. However, there were no group differences with regard to other competency or outcome ratings, which would point to selection effects that might have affected our overall result patterns.

General Discussion

Interdisciplinary work is promising regarding possible innovations, yet is experienced as being particularly demanding. We argue that competencies of individuals in interdisciplinary teams help to overcome hurdles and thus enable the utilization of interdisciplinary potential. We set out to explore what kind of competencies support successful interdisciplinary work.

Our research is based on a mixed-methods approach. We combined a study of qualitative data and inductive model development with two subsequent deductive tests. Our findings suggest that interdisciplinary competencies can be described by four related model dimensions: *initiative for exchange, target group-specific communication, knowledge integration* and *reflection*. These dimensions resonate well with existing literature on singular challenges in interdisciplinary work (Bromme, 2000; Lattuca et al., 2012; Steinheider et al., 2009). The model combines these dimensions to cover a broader scope of competencies in interdisciplinary work. Yet, our inductive study also enabled the review of competencies for their specificity for interdisciplinary endeavours and thus to advance and condense the model of Brandstädter and Sonntag (2016). Moreover, the first quantitative study of the model in a sample of interdisciplinary practitioners revealed both experience in interdisciplinary work and the significance of interdisciplinarity for the current job as relevant predictors for self-reported competencies. These results provide first clues to competency development. The second quantitative study complemented the results by showing convergent validity with

respect to teamwork self-efficacy, preference for teamwork, task interdependence, and managerial support, as well as incremental validity with respect to general teamwork competencies in predicting team outcomes.

Theoretical and Practical Implications

Disciplinary perspectives are developed through socialization within a certain academic or occupational field. Disciplinary perspectives are a deep-level characteristic that shapes different aspects of everyday work. This characteristic is part of what makes interdisciplinary work difficult to do (Epstein, 2005). As a consequence, interdisciplinary work differs from general teamwork with regard to requirements, demands, and competencies. The model presented here helps to understand these differences and integrates previous research on challenges of interdisciplinary work such as communication across disciplinary borders and knowledge integration (Bromme, 2000; Steinheider et al., 2009).

Previous research has focused on the team level or organizational means of supporting disciplinary or functionally diverse teams. Our research complements this perspective by zooming into individual competencies in the interdisciplinary teamwork context. The results indicate that a single individual with his or her competencies can help make teams successful. From our point of view, a team is not an abstract construct that can be studied independently from its members; rather, individual competencies and characteristics are the basis for team outcomes. These individual competencies can then be transferred from one collaboration to another, which makes them particularly relevant for staffing decisions.

In addition, it is worth discussing what makes a discipline. Traditional definitions of interdisciplinarity (Newell, 2001; Repko et al., 2014; Szostak, 2002) build upon the history of science and how academic disciplines evolved. Nevertheless, socialization into a “discipline” also happens outside of the ivory tower of academia. Interdisciplinarity has been a trend in science in the past decades; in industrial settings, however, teams of experts from different fields have been common even longer. As we aimed at sampling fewer academics for Study 3,

the question arose as to whether disciplinary perspectives are tied to university degrees or might be developed in non-academic occupations such as midwifery as well. This issue is not addressed in definitions of interdisciplinarity, and we decided to include occupations with a strong sense of disciplinarity and relatively clear understandings of responsibilities, as can be observed in health occupations (nursing, midwifery, physiotherapists) or creative occupations (stage designer, conductor). The present model of interdisciplinary competencies can be of practical use in personnel selection and development. The model can help to develop specific behavioural measures in addition to the questionnaire instrument introduced here. These specific instruments can be used for purposes of personnel selection (e.g., in an assessment centre), for self-reflection, as well as for evaluation of interdisciplinary collaborations and personnel development. Moreover, the model of interdisciplinary competencies can provide a basis for specific interventions to foster interdisciplinary collaboration.

Strengths, Limitations and Future Research

The reported studies contribute to the theoretical understanding of how individuals can achieve success in interdisciplinary project teams. The model enables the analysis of an individual's competencies as a driving mechanism for interdisciplinary cooperation.

As with any research, strengths and weaknesses have to be weighed. A clear strength is the mixed-method approach. As qualitative theory-building and quantitative theory-testing complement each other (Eisenhardt & Graebner, 2007), we decided to utilize both research strategies to strengthen the case for our model. The consistency of results across different research methodologies indeed accomplishes that objective. Nevertheless, a limitation of the quantitative studies concerns the self-report data for competencies. The construct of competencies calls for performance data. With regard to outcome measures, we implemented a peer-report in the third study to avoid common method variance. We propose a new competency model which is parsimonious and specific for interdisciplinary collaborations. As

such, it advances previous work and identifies relevant competency dimensions. The clear focus on competencies is also apparent in the self-report measure we developed.

Interdisciplinary collaborations are manifold: they can be project based or ongoing, they can happen within one organizational unit or across organizations, and the disciplines involved can be closely related or rather distant. This multitude of manifestations of interdisciplinarity reflects how common interdisciplinary work has become, but also reflects very different working conditions and arrangements. Interdisciplinary competencies are relevant in all of these varied contexts; nevertheless, it is difficult to compare these collaborations. Our studies tried to represent this diversity to develop a model of interdisciplinary competencies that is not limited to a certain mode of collaboration or industry. However, in two of our studies, research teams were overrepresented. Fortunately, in Study 3, we overcame this potential bias. But it has to be acknowledged that interdisciplinary teams differ in many respects (e.g., hierarchy, distance of disciplines, goals, level of integration) and that controlling for these differences was not in focus in our designs.

Future research should overcome the method-specific limitation by utilizing other research measures with a focus on performance, such as behavioural data from the field or lab. The self-report of competencies we considered here may differ from measures of interdisciplinary competencies obtained from reports of colleagues or supervisors or from behavioural observations. Researchers should include performance measures and examine the relations between them and self-reported interdisciplinary competencies. Our study suggests that experiences in interdisciplinary work increase certain interdisciplinary competencies. Future research should address the mechanisms and conditions for competency development on the job, as this understanding is crucial for future applications and possible interventions. In addition, one limitation is the mostly cross-sectional nature of our data, which does not allow determining causality; thus, relevant questions regarding development mechanisms remain unanswered.

Concluding Remarks

Interdisciplinarity holds the potential for innovation and progress in many areas of science and everyday life. Part of this potential is lost due to difficulties in interdisciplinary collaboration. The theoretical understanding of individuals' competencies as a basis for successful collaborations requires a competency model. There is a clear necessity to better understand mechanisms of competency development and competencies' relevance for team success. This study hopefully serves as a first step in this important endeavour.

References

Asparouhov, T., & Muthén, B. (2009). Exploratory structural equation modeling. *Structural Equation Modeling, 16,* 397–438. doi:10.1080/10705510903008204

Bandura, A. (1994). Self-efficacy. In V. S. Ramachaudran (Ed.), *Encyclopedia of human behavior* (Vol. 4, pp. 71-81). New York: Academic Press.

Bandura, A., & Schunk, D. H. (1981). Cultivating competence, self-efficacy, and intrinsic interest through proximal self-motivation. *Journal of Personality and Social Psychology, 41*, 586–598.

Boyatzis, R. E. (2008). Competencies in the 21st century. *Journal of Management Development, 27*(1), 5-12. doi:10.1108/02621710810840730

Brandstädter, S., & Sonntag, K. (2016). Interdisciplinary collaboration: How to foster the dialogue across disciplinary borders? In B. Deml, P. Stock, R. Bruder, & C. Schlick (Eds.), *Advances in ergonomic design of systems, products and processes* (pp. 395–410). Berlin: Springer.

Bromme, R. (2000). Beyond one's own perspective: The psychology of cognitive interdisciplinarity. In P. Weingart & N. Stehr (Eds.), *Practising interdisciplinarity* (pp. 115–133). Toronto: University of Toronto Press.

Bronstein, L. R. (2003). A model for interdisciplinary collaboration. *Social Work, 48,* 297–306. doi: 10.1093/sw/48.3.297

Bunderson, J. S. (2003). Team member functional background and involvement in management teams: direct effects and the moderating role of power centralization. *Academy of Management Journal, 46,* 458-474.

Campion, M. A., Medsker, G. J., & Higgs, A. C. (1993). Relations between work group characteristics and effectiveness: Implications for designing effective work groups. *Personnel Psychology, 46,* 823-850.

Cheung, S. Y., Gong, Y., Wang, M., Zhou, L. B., & Shi, J. (2016). When and how does functional diversity influence team innovation? The mediating role of knowledge sharing and the moderation role of affect-based trust in a team. *Human Relations, 69*, 1–25. doi:10.1177/0018726715615684

Clark, H. H. (1996). *Using language*. Cambridge, UK: Cambridge University Press.

Cronin, M. A., & Weingart, L. R. (2007). Representational gaps, information processing, and conflict in functionally diverse teams. *Academy of Management Review, 32*, 761-773

Cummings, J. N., & Kiesler, S. (2008). *Who collaborates successfully? Prior experience reduces collaboration barriers in distributed interdisciplinary research.* Paper presented at the Computer Supported Cooperative Work, San Diego, California.

Devlieger, I., & Rosseel, Y. (2017). Factor score path analysis: an alternative for SEM? *Methodology, 13*, 31-38. doi:10.1027/1614-2241/a000130

Eby, L. T., & Dobbins, G. H. (1997). Collectivistic orientation in teams: an individual and group-level analysis. *Journal of Organizational Behavior, 18*, 275-295.

Eisenhardt, K. M., & Graebner, M. E. (2007). Theory building from cases: Opportunities and challenges. *Academy of Management Journal, 50*(1), 25–32.

Epstein, S. L. (2005). Making interdisciplinary collaboration work. In S. J. Derry, C. D. Schunn, & M. A. Gernsbacher (Eds.), *Interdisciplinary collaboration. An emerging cognitive science* (pp. 245–263). New York: Lawrence Erlbaum Associates.

Ericsson, K. A., & Simon, H. A. (1993). *Protocol analysis: Verbal reports as data*. Cambridge: MIT Press.

Flanagan, J. C. (1954). The critical incident technique. *Psychological Bulletin, 51*, 327–359. doi:10.1037/h0061470

Halfhill, T. R., & Nielsen, T. M. (2007). Quantifying the "softer side" of management education: an example using teamwork competencies. *Journal of Management Education, 31*(1), 64-80.

Heidemeier, H., & Moser, K. (2009). Self-other agreement in job performance ratings: A meta-analytical test of a process model. *Journal of Applied Psychology, 94*, 353-370. doi:10.1037/0021-9010.94.2.353

Hertel, G., Konradt, U., & Orlikowski, B. (2004). Managing distance by interdependence: Goal setting, task interdependence, and team-based rewards in virtual teams. *European Journal of Work and Organizational Psychology, 13*(1), 1-28. doi:10.1080/13594320344000228

Koch, A., Strobel, A., Kici, G., & Westhoff, K. (2009). Quality of the critical incident technique in practice: Interrater reliability and users' acceptance under real conditions. *Psychological Science Quarterly, 51*, 3–15.

Krapp, A. (2002). Structural and dynamic aspecs of interest development: theoretical considerations from an ontogenetic perspective. *Learning and Instruction, 12*, 383–409.

Lattuca, L. R., Knight, D. B., & Bergom, I. M. (2012). *Developing a measure of interdisciplinary competence for engineers*. Paper presented at the Conference of the American Society for Engineering Education (ASEE), San Antonio, TX.

Ley, T., Lindstaedt, S. N., & Albert, D. (2005). *Supporting competency development in informal workplace learning*. Paper presented at the Conference for Professional Knowledge Management, Kaiserslautern, Germany.

Lindell, M. K., & Whitney, D. J. (2001). Accounting for common method variance in cross-sectional research designs. *Journal of Applied Psychology, 86*, 114-121. doi:10.1037//0021-9010.86.1.114

Marsh, H. W., Muthén, B., Asparouhov, T., Lüdtke, O., Robitzsch, A., Morin, A. J. S., & Trautwein, U. (2009). Exploratory structural equation modeling, integrating CFA and EFA: Application to students' evaluations of university teaching. *Structural Equation Modeling, 16*, 439–476. doi:10.1080/10705510903008220

Maynard, M. T., & Gilson, L. L. (2014). The role of shared mental model development in understanding virtual team effectiveness. *Group & Organization Management, 39*, 3–32. doi:10.1177/1059601113475361

Maynard, M. T., Mathieu, J. E., Rapp, T., & Gilson, L. L. (2012). Something(s) old and something(s) new: Modeling drivers of global virtual team effectiveness. *Journal of Organizational Behavior, 33*, 342-365. doi:10.1002/job.1772

Morin, A. J. S., Marsh, H. W., & Nagengast, B. (2013). Exploratory structural equation modeling. In G. R. Hancock & R. O. Mueller (Eds.), *Structural equation modeling: A second course* (pp. 395–437). Charlotte, NC: Information Age Publishing, Inc.

Newell, W. H. (2001). A theory of interdisciplinary studies. *Issues in Integrative Studies, 19*, 1–25.

Reich, S. M., & Reich, J. A. (2006). Cultural competence in interdisciplinary collaborations: A method for respecting diversity in research partnerships. *American Journal for Community Psychology, 38*, 51–62. doi: 10.1007/s10464-006-9064-1

Repko, A. F., Szostak, R., & Buchberger, M. P. (2014). *Introduction to interdisciplinary studies*. Los Angeles, CA: Sage.

Rogers, Y., Scaife, M., & Rizzo, A. (2005). Interdisciplinarity: An emergent or engineered process? In S. J. Derry, C. D. Schunn, & M. A. Gernsbacher (Eds.), *Interdisciplinary Collaboration* (pp. 265–286). Mahwah, NJ: Lawrence Erlbaum.

Sandberg, J. (2000). Understanding human competence at work: An interpretative approach. *Academy of Management Journal, 43*(1), 9-25.

Steinheider, B., Bayerl, P. S., Menold, N., & Bromme, R. (2009). Entwicklung und Validierung einer Skala zur Erfassung von Wissensintegrationsproblemen in interdisziplinären Projektteams (WIP) [Development and validation of a scale for knowledge integration problems in interdisciplinary teams]. *Zeitschrift für Arbeits- und Organisationspsychologie, 53*, 121–130. doi:10.1026/0932-4089.53.3.121

Stevens, M. J., & Campion, M. A. (1994). The knowledge, skill, and ability requirements for teamwork: Implications for human resource management. *Journal of Management, 20,* 503–530.

Sung, N. S., Gordon, J. I., Rose, G. D., Getzoff, E. D., Kron, S. J., Mumford, D., . . . Kopell, N. J. (2003). Educating future scientists. *Science, 301,* 1485. doi:t10.1126/science.10866133

Szostak, R. (2002). How to do interdisicplinarity: Integrating the debate. *Issues in Integrative Studies, 20,* 103–122.

van Ginkel, W. P., & van Knippenberg, D. (2008). Group information elaboration and group decision making: The role of shared task representations. *Organizational Behavior and Human Decision Processes, 105,* 82–97. doi:10.1016/j.obhdp.2007.08.005

van Knippenberg, D., De Dreu, C. K. W., & Homan, A. C. (2004). Work group diversity and group performance: An integrative model and research agenda. *Journal of Applied Psychology, 89,* 1008–1022. doi:10.1037/0021-9010.89.6.1008

Don't Take it for Granted:
Employees' Individual Knowledge Integration Competency
in Interdisciplinary Work

Anna M. Claus, Christian L. Burk & Bettina S. Wiese

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Abstract

Interdisciplinary work requires connecting separate bodies of knowledge to combine different fields of expertise. The process of discussing and incorporating different viewpoints has been described as knowledge integration. Past research has shown that knowledge integration in a team is positively associated with performance outcomes. The present study aims at advancing our understanding of the role of individual abilities for interdisciplinary success. It takes an individual level perspective on knowledge integration in interdisciplinary work by investigating the influence of an individual's knowledge integration competency on project success. In a sample of 154 dyads of employees working together interdisciplinarily, both self-reported and peer-reported knowledge integration competencies were positively related with project success. In addition, the role of common ground in terms of disciplinary closeness is explored, and future research prospects on individual abilities in interdisciplinary collaborations are outlined.

Keywords: interdisciplinarity; individual competencies; knowledge integration; disciplinary closeness; organizational behavior; Germany

Employees' Individual Knowledge Integration Competency in Interdisciplinary Work

Interdisciplinary teams work on big current issues such as sustainable development, future energy solutions, and modern mobility concepts. These challenges cannot be adequately addressed by means of a single discipline alone (Nightingale & Scott, 2007; Pennington, 2015; Sung et al., 2003). Clearly, interdisciplinarity appears to be a necessity for innovation and progress. However, if it comes to actual information use and performance in groups with people from different disciplinary backgrounds, interdisciplinarity puts remarkably high demands on the individuals involved (Dahlin, Weingart, & Hinds, 2005).

To unfold interdisciplinarity's potential in solving central research problems conflicting viewpoints and information which stems from different disciplinary backgrounds need to be discussed and incorporated into decision making. This process has been described as knowledge elaboration in the categorization–elaboration model (CEM; van Knippenberg et al., 2004) or as knowledge integration in the literature on interdisciplinary work (Rafols, 2014; Steinheider, 2012). Previous research has shown that knowledge elaboration improves performance of demographically and educationally diverse teams (Hoever et al., 2012; Homan et al., 2007; Luan et al., 2016).

Knowledge integration unfolds in groups but is driven by the abilities and skills of the team members. Prerequisites of knowledge integration in diverse teams have been explored on a group-level basis (e.g., of gender diversity in experimental settings, see Hoever et al., 2012; Homan et al., 2007). However, knowledge integration on the team level is not random, but rather dependend on the competencies of group members. It is a complex cognitive skill, which allows an individual to understand and combine different bodies of knowledge to create a new perspective.

The aim of this study is to provide short self-report and peer-report measures of knowledge integration competency and, based on that, to explore the individual level perspective on knowledge integration in interdisciplinary collaborations. We consider team

members' knowledge integration competency as a central predictor of success in interdisciplinary projects. This study is a first step to test interindividual differences regarding knowledge integration. By analyzing individual level competencies, we create grounds for future activities in human resource management to optimize personnel selection and development of staff involved in interdisciplinary collaborations.

Knowledge Integration

In the diversity literature, results on the relationship between team heterogeneity and performance outcomes have been mixed (for metaanalytic results see Webber & Donahue, 2001). In the past, researchers have suggested that demographic diversity concerning, for instance, gender or age, leads to conflicts and decreases performance and well-being, while functional diversity, e.g., different disciplinary backgrounds, increases the available information and improves the decision making processes (see Williams & O'Reilly, 1998). Due to conflicting evidence, van Knippenberg et al. (2004) propose that it is not the kind of diversity, but the elaboration of task-relevant information, that is crucial to making diverse teams successful.

In the literature, the terms knowledge integration and knowledge elaboration are mostly used interchangeably; knowledge integration, however, emphasizes the process-related nature of combining different information and is thus used here. In the CEM, knowledge elaboration is described as "group members' exchange, discussion, and integration of ideas, knowledge, and insights relevant to the group's task" (van Knippenberg et al., 2004, p. 1010). Rafols (2014) defines knowledge integration as "the process bringing into relation bodies of knowledge or research practice hitherto unrelated or distant" (p. 2). In our view, this process lies at the core of successful interdisciplinary work. Consequently, successful interdisciplinary work depends on team members who engage in knowledge integration by making an effort to understand the input of others, linking new information to their own knowledge, sharing information to enable others to integrate knowledge, and generating a framework of

interconnected information. Knowledge integration, thus, is a complex cognitive skill and is experienced as particularly difficult (Dahlin et al., 2005).

In the past, the effects of knowledge integration on performance have been shown on the team level only. In an experimental study, Homan et al. (2007) manipulated informational diversity in gender-diverse teams of students. Based on video analyses of group discussions, team-level information elaboration had a positive effect on team performance (Homan et al., 2007). In another lab experiment, students were assigned to different roles on the managerial board of a theater (e.g., financial or artistic; Hoever et al., 2012). Team-level information elaboration (analyzed from group discussions) was found to mediate the effect of diversity on team creativity but only after inducing perspective-taking. Whereas the aforementioned studies were based on student samples, Luan et al. (2016) studied real-world teams. They found that the capability for knowledge integration of a team moderated the effect of educational diversity on team creativity. More precisely, there was an inverted U-shaped relationship between educational diversity and creativity in teams with low knowledge integration capability, while there was no effect of educational diversity on creativity in teams with high knowledge integration capability. In sum, there is first evidence that team level knowledge integration has a positive impact on team performance.

We argue that individual skills play a crucial role in enabling knowledge integration in interdisciplinary collaborations. Individuals and their abilities pave the way for team effectiveness and promote knowledge integration and interdisciplinary thinking on a team level (Pennington, 2015). Therefore, we expect:

H1: An individual team member's knowledge integration competency influences perceived project success.

The Role of Disciplinary Closeness

In studying interdisciplinarity, the defining academic disciplines and their interdependencies have to be taken into account. Academic disciplines have emerged over

centuries based on both organizational structures and the knowledge domains they study (Becher & Trowler, 2001). The comparison of disciplines can be based on common theories, methods, or subjects of interest (Aboelela et al., 2007). Biglan (1973) introduced a classification of academic disciplines based on ratings of researchers in different institutions and disciplines. He suggests that the cognitive style of a discipline can be described by the use of a paradigm (hard vs. soft science), its concern with practical application (pure vs. applied science), and whether it studies life systems (life vs. non-life science).

How does the relationship between different disciplines affect interdisciplinary collaborations? Working with people from a distant discipline is challenging, as there is hardly any common ground regarding approaches, methods and solutions (Clark, 1996). Common ground can be created either through communities people are members of – such as academic disciplines – (so called communal common ground) or through personal experiences with one another (personal common ground). A large overlap between disciplines in terms of methods or theories might improve the collaboration experience because the communal common ground facilitates information exchange (Clark, 1996). Dahlin et al. (2005) investigated MBA-students working on case studies. They found that educational diversity (i.e., study major diversity) increased the range and depth of information used in the team only up to a certain point, resulting in an inverted U-shaped relationship between diversity and information exploration. Highly interdisciplinary teams did not fully explore available information and performed their analyses rather superficially, while moderately interdisciplinary teams benefitted from diversity. This reflects the idea of a saturation point, above which groups do not benefit from more diversity (Cohen & Levinthal, 1990). Furthermore, educational diversity was negatively related to knowledge integration at the group level. In other words, highly diverse teams were less able to connect and organize information and ideas. Consequently, we assume that high interdisciplinarity as a specific diversity puts excessive demands on teams regarding information elaboration and integration.

In collaborations between distant disciplines, an increased necessity for knowledge integration exists compared to interdisciplinary endeavors of more closely related disciplines. As a consequence, individuals who meet these demands with their knowledge integration competency can better support team project success. Knowledge integration competency influences performance outcomes, but even more so in far-distant interdisciplinary collaborations.

H2: Disciplinary closeness moderates the relationship of knowledge integration and project success, such that knowledge integration increases project success particularly in collaborations between distant disciplines.

Method

Sample

We tested our hypotheses based on self- and peer-ratings of employees from interdisciplinary settings. Participants were 326 persons with experience in interdisciplinary work as target persons. We emailed people working in interdisciplinary research projects and in companies that describe themselves as interdisciplinary. For an external rating, target persons were asked to invite a peer from another discipline with whom they were currently working together interdisciplinarily. As not all peers responded, the total sample consists of 154 dyads (response rate of peers: 47.2%). Participants had the opportunity to take part in a lottery with 15 cash prizes of €250 (~ 300 USD) for target persons and 15 cash prizes of €100 (~ 125 USD) for peers. We decided to employ both self- and peer-report, because both methods probably contain unique variance based on the different perspectives. Bringing together these views should provide a more holistic perspective.

The recruitment process targeted interdisciplinary research groups, thus most participants worked in academia and nearly all of them (98.1%) had completed a university degree. Target persons (50.0% female) were on average 32.98 years old (range 24–62; *SD* = 7.61) and represented a variety of disciplines: 19.7% had a degree in the humanities, 23.6% in

social sciences, 26.1% in mathematics or natural sciences and 10.8% in engineering sciences. Peers (55.2% female) were on average 33.20 years old (range 24–58; *SD* = 7.58) and had also various disciplinary backgrounds (humanities: 17.8%, social sciences: 24.2%, mathematics / natural sciences: 23.6%, engineering: 8.9%). Most peers described their relation to the target person as being project partners (50.7%) or colleagues (31.6%); thus, there is reason to believe that the dyads are often part of a team with more than two members. We grouped disciplines of target persons and peers into disciplinary groups based on the classification system of the German federal statistics office[9] (e.g., history into humanities and chemistry into natural sciences; DeStatis, 2015); 40.8% of the interdisciplinary dyads came from the same disciplinary group and thus their disciplines are distinct but closely related. In addition, we applied the classification scheme by Biglan (1973) and calculated on how many dimensions (hard vs. soft, pure vs. applied, life vs. non-life) an overlap between target person's and peer's discipline could be observed. Dyads shared, on average, 1.5 dimensions (30.6% none, 15.3% one dimension, 26.8% two dimensions and 27.4% all three dimensions).

Instruments

We adapted the knowledge integration scale of Steinheider et al. (2009) to refer to individual competencies instead of team processes, e.g., "When I work interdisciplinarily, I am good at connecting and integrating knowledge from different disciplines." Knowledge integration was measured by five items on a 6-point rating scale (1 = *I don't agree*; 6 = *I fully agree*; α = .74; see Table 1 and 2). For the peer-report, items of knowledge integration

[9] The DeStatis system differentiates between eight fields of study: humanities, sports, law/economical/social sciences, math/natural sciences, medicine/health sciences, agricultural/nutritional/veterinarian sciences, engineering sciences, arts/performing arts The Classification of Instructional Programs (CIP; National Center for Education Statistics, 2010) provides more detail and differentiates between 47 programs on the most aggregated level. But statistics from the US Census Bureau (U.S. census bureau & Ryan, 2012) on the fields of degrees resemble the German system, while offering more differentiation in the social sciences (e.g., by separating psychology, social sciences and education)

competency were adapted so the peers would report on the target person's competencies (α = .77).

Table 1

Items of the knowledge integration scale (self-report version)

Item no.	Item text
1	In interdisciplinary work, I succeed in understanding the reasoning of other disciplines.
2	When I hear something new from another discipline, I find it difficult to create links to my own knowledge. *
3	When I work interdisciplinarily, I am good at connecting and integrating knowledge from different disciplines.
4	In interdisciplinary work, I succeed in connecting different disciplines regarding content.
5	In interdisciplinary work, I can easily understand what the work of other team members involves.

Note. * = inverted item. Cronbach's α = .74 for self-report, Cronbach's α = .77 for peer-report.

We asked both target persons and peers about their collaboration (e.g., how long they have worked together). During data collection, three target persons contacted us because they had difficulties to obtain a peer report from the colleague they had originally invited and so they changed the peer. As a consequence, self- and peer-reported information on the collaboration history did not match. Because this might be true for other participants as well, we decided to include only peer-reports on the collaboration history in our analyses.

To operationalize disciplinary closeness, different measures were taken. First, we asked peers to rate the relation between the disciplines using one item "Different disciplines can be related or distant from each other. For example, the basic elements, methods, and content of the disciplines civil engineering and mechanical engineering are more similar than those of mechanical engineering and law. How would you rate the disciplinary closeness between your own discipline and your colleague's?" (6-point scale: 1 = *very close* to 6 = *very distant*). Second, we calculated whether target persons and peers would be grouped in the same disciplinary group according to the German federal statistics office (DeStatis, 2015).

Third, we used the Biglan-classification (1973) regarding how many dimensions the target person's and the peer's disciplines share (from zero to three dimensions).

Table 2

Descriptive statistics and correlations among the variables

		M	*SD*	min	max	1	2	3	4
1	Knowledge integration competency (self-report)	4.72	.64	2.20	6.00				
2	Knowledge integration competency (peer-report)	4.93	.68	2.60	6.00	.04			
3	Disciplinary closeness (peer-report)	3.11	1.33	1.00	6.00	.14	-.03		
4	Shared Biglan dimensions	1.51	1.19	0.00	3.00	-.11	.05	-.31***	
5	Project success (peer-report)	3.76	.68	2.00	5.00	.20**	.31***	.25***	-.02

Note. ***p < .001; **p < .01

Measuring project success is complex and "to think that one can objectively measure the success of a project is an illusion" (de Wit, 1988, p. 169). Usually, supervisor ratings are used when full-scope evaluations of objectives, costs and outcomes are not feasible (e.g., Crawford, 2005). In interdisciplinary collaborations, project objectives, costs and outcomes are often ambiguous. In addition, collaborators often report to different supervisors, as departments are structured disciplinarily. Therefore, we decided that peers should rate the project outcome. As very short scales from collaboration outcomes have successfully been used before (Valls, González-Romá, & Tomás, 2016), we decided on a one-item measurement of project success ("Has the project reached the expected results so far?"), which only the peers rated on a 5-point rating scale (1 = *So far, the cooperation falls short of our expectations.*; 5 = *The cooperation exceeds all expectations.*).

Analytical Approach

Before testing our hypotheses with regression analysis, we investigated the relationship between self-reported and peer-reported knowledge integration competency using confirmatory factor analysis (CFA). As meta-analytic results (Heidemeier & Moser, 2009) provide evidence that self- and other-ratings are only slightly correlated, we assumed that both data sources provide unique aspects and that it might be beneficial to include both in the statistical models.

Results

Confirmatory Factor Analyses

We first modeled self- and peer reported knowledge integration competency as separate but correlated latent variables. While the model fit was good (χ^2 = 44.98, *df* = 34, *p* = .10; CFI = .97; TLI = .96; RMSEA = .05; SRMR = .05), the correlation of these latent variables was not significant (*r* = .07). As a consequence of the low covariance between self-reported and peer-reported knowledge integration competency, we decided against modeling a higher order latent variable of knowledge integration, as it would include only little common variance, does not affect model fit, and might hamper measurement reliability. Furthermore, we also tested models of a common latent knowledge integration variable and a separate method factor to explain specific aspects of self- and peer-report (see Eid, Lischetzke, & Nussbeck, 2006). These models were either not identified or did not converge.

In conclusion, CFA-results suggest considering both data sources as relevant separate variables. Thus the structural equation models to test our hypothesis included self- and peer-report of knowledge integration competency separately.

Hypotheses Testing

Using path analysis, we tested the hypothesized effect of knowledge integration competency on project success (H1). Both knowledge integration competency in self-report (*b* = .31; *p* < .05) and peer-report (*b* = .43; *p* = .001) were significant predictors for project

success (see Figure 1, R^2 = .13). A comparison of the regression parameters using the Wald test showed that there is no significant difference (Wald test (1) = .34; p = .56) between the effects of self- and peer-reported knowledge integration competency.

Because the R package lavaan (Rosseel, 2012) does not offer moderation analysis featuring latent variables, we implemented two different strategies: (a) we calculated factor

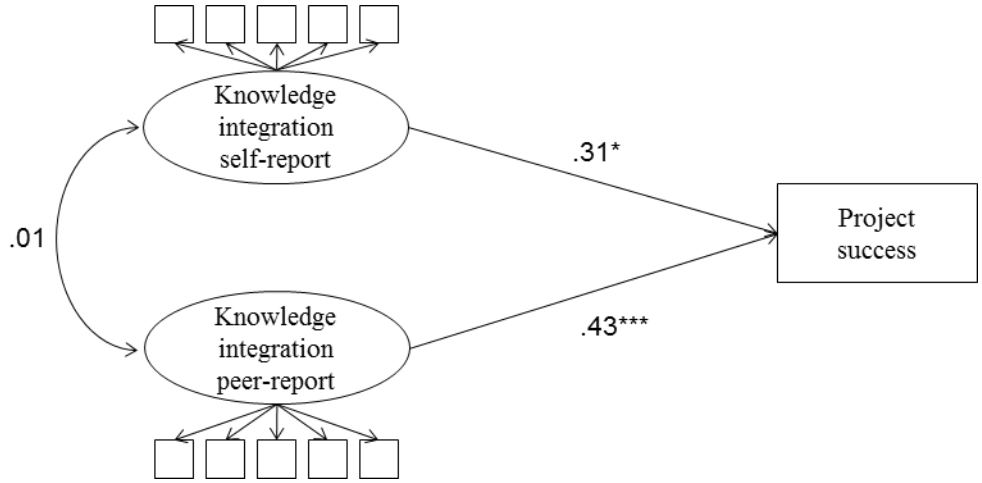

Figure 1. Path model with two latent indicators showing the effects of knowledge integration competency on project success. Unstandardized coefficients.
Model fit: χ^2 = 56.10, df = 42, p = .07; CFI = .96; TLI = .95; RMSEA = .05; SRMR = .05

scores of the previously latent variables and (b) we replicated the analyses using Mplus (Muthén & Muthén, 1998-2017). There were only marginal differences between the two strategies, if any. Therefore, we restrict our report to the results of the analyses based on factor scores. To test the hypothesized moderation of disciplinary closeness on the effect of knowledge integration competency on project success (H2), we first used the peer-report of disciplinary closeness as a moderator. Peer-reported disciplinary closeness did not moderate the effects of self- and peer-reported knowledge integration competency on project success. However, we found a main effect of disciplinary closeness on project success (b = .13, p = .001; R^2 = .18). Second, we tested whether belonging to the same disciplinary group moderates the effect of knowledge integration on project success. There was no main effect (b = -.11; p = .41) or moderation (self-report: b = .17; p = .59; peer-report: b = -.07; p = .81).

Third, the shared Biglan-categories did not moderate the effects of knowledge integration competency on project success (self-report: b = .15; p = .20; peer-report: b = .01; p = .96). Neither could we find a main-effect of shared Biglan dimensions on project success (b = -.01; p = .76). In sum, there was no support for H2.

Post-hoc Analyses

As the correlation between self- and peer-report was very low, we decided to explore the relation between both in more detail. We assumed that a larger common ground between target persons and peers might increase the consensus on the knowledge integration competency of target persons. This common ground could be either created by a longer history of working with each other (personal common ground) or a similar academic socialization (communal common ground) by related disciplinary perspectives. As a consequence, we tested whether the duration of the collaboration moderates the association between self- and peer-reported knowledge integration competency. Again, we used centered factor scores of knowledge integration competencies for the regression model. As suggested by the bivariate correlation, the self-reported knowledge integration competency is not a predictor for the peer-reported knowledge integration competency (b = .04; p = .65). This effect is not moderated by the duration of the collaboration (b = -.01; p = .94).

In the same vein, we tested disciplinary closeness as a moderator for the relationship between self- and peer-reported knowledge integration competency. First, we used the peer-report of disciplinary closeness as an operationalization for disciplinary closeness. Again, neither a direct effect (b = -.01; p = .64) nor moderation was found (b = -.03; p = .60). Second, we tested whether belonging to the same disciplinary group moderates the low association between self- and peer-reported knowledge integration competency. Again, we did not find either a main effect (b = -.02; p = 59) or a moderation (b = -.03; p = .55). Third, we employed the overlap in the dimensions of the discipline according to Biglan (1973) as a moderator. But, again, no significant moderation of the association between self- and peer-

reported knowledge integration competency was found (b = .01; p = .89). To conclude, there was no empirical evidence for greater consensus in the evaluation of knowledge integration competency of the target person depending on personal (duration of the collaboration) or communal (disciplinary closeness) common ground.

Discussion

We set out to explore the role of an individual team member's competency for knowledge integration in achieving successful interdisciplinary work. The results indicate that both self-rated knowledge integration competency and peer-rated knowledge integration competency are positively related to the project success in interdisciplinary work.

Working in interdisciplinary teams is challenging as members are confronted with unfamiliar concepts and are required to connect those to their own areas of expertise. Therefore, an individual's abilities and skills in elaborating and integrating different fields of knowledge are of the utmost importance to successful interdisciplinary collaborations. As team members bring their knowledge integration competencies into the team (van Knippenberg et al., 2004), they promote knowledge integration processes on the team level which have been shown before to influence team performance (Hoever et al., 2012; Homan et al., 2007).

Interdisciplinarity can include collaborations of closely related or far distant disciplines. Although common ground between distant disciplines is smaller, there was no support for the hypothesis that knowledge integration competency is of higher importance for project success in collaborations where wide disciplinary gaps have to be bridged. This might be due to collaborators not being aware of the necessity for knowledge integration in collaborations of closely related disciplines, while it is more obvious that knowledge integration is a prerequisite for successful work if disciplines have only little in common (e.g., Biglan dimensions).

A clear strength of our study is that we used data from real-world interdisciplinary teams. Another strength is that we referred to different informational sources. We did not want to solely rely on self-report data regarding the target person's knowledge integration competency and the project success. Therefore, we additionally collected ratings of a peer who worked with the target persons but had a different disciplinary background.

Self- and other ratings of performance commonly show only little agreement (Heidemeier & Moser, 2009) and our results are no exception. As raters have to pay attention to cues, categorize and integrate them to an overall rating of a competency, different perspectives and opportunities for observation may lead to varying ratings of competency. Regarding knowledge integration as a cognitive task, cues might be limited and as a result, competency evaluation of target persons and their project partners or colleagues might differ. Not sharing a disciplinary background, and thus a common knowledge base, increases the difficulties of assessing another person's knowledge integration competency. As a consequence, we included both sources of competency ratings separately into our analyses.

To shed light on the little consensus between target persons and peers regarding the target person's knowledge integration competency, we followed the idea that increased common ground improves rater agreement of the target person's knowledge integration competency. According to Clark (1996), common ground can be either communal or personal, rooted in communities or in personal experience with one another. There was, however, no empirical support for disciplinary closeness (a proxy for communal common ground) or duration of collaboration (a proxy for personal common ground) strengthening the convergence of self- and peer-ratings.

Future Research Directions and Practical Implications

Future research should target specific limitations of our research design to deepen our understanding of the role of individual knowledge integration competency for interdisciplinarity. As we obtained a peer-rating for project success, this outcome shares a

common source with the peer-rated knowledge integration. This might explain the higher association between the peer-rated knowledge integration competency and the project outcome compared to self-rated knowledge integration competency. Future studies might include behavioral data as a measure of knowledge integration competency or other performance outcomes. In addition, to draw a more complete picture of an individual's impact on successful interdisciplinary work, not only competencies but also motivation should be taken into account. Also, we recommend including complete interdisciplinary teams in future studies as the dyadic data studied here only gives limited information on the entire team structure. One might speculate, for instance, that positive cross-over effects occur if one team member actively demonstrates their effort in knowledge integration. This behavior might motivate other team members to also get more cognitively involved. Investigating these kinds of research questions to bridge the gap from the individual to the group, requires not only more complex designs but also more advanced statistical analyses taking nested data into account.

In terms of practical implications and with respect to staffing decisions in interdisciplinary teams, both individual expert knowledge and knowledge integration competency should be taken into account. Furthermore, knowing that individuals drive team level processes and that "knowledge integration is fundamentally an individual learning issue" (Pennington, 2015, p. 302), interventions and training to improve interdisciplinary competencies should explicitly target individuals' ability for knowledge integration.

In summary, interdisciplinary work is expected to be of utmost importance for progress in science and for dealing with great societal challenges (Nightingale & Scott, 2007). However, to fulfill its promise, individuals involved in interdisciplinary endeavors have to invest cognitive effort and develop competencies in bringing together different fields of expertise. The results of this study encourage establishing an individual level perspective of knowledge integration in diverse teams. Our study indicates that the competency for

knowledge integration of a single person can help achieve project success in an interdisciplinary team. As a consequence, individuals and their knowledge, skills and abilities drive team level processes and thus should be studied in much greater detail.

References

Aboelela, S. W., Larson, E., Bakken, S., Carrasquillo, O., Formicola, A., Glied, S. A., . . . Gebbie, K. M. (2007). Defining interdisciplinary research: Conclusions from a critical review of the literature. *Health Services Research, 42*, 329 - 346. doi:10.1111/j.1475-6773.2006.00621.x

Becher, T., & Trowler, P. R. (2001). *Academic tribes and territories. Intellectual enquiry and the culture of disciplines*. Ballmoor: SRHE.

Biglan, A. (1973). The characteristics of subject matter in different academic areas. *Journal of Applied Psychology, 57*, 195-203. doi:10.1037/h0034701

Clark, H. H. (1996). *Using language*. Cambridge, UK: Cambridge University Press.

Cohen, W. M., & Levinthal, D. A. (1990). Absorptive capacity: A new perspective on learning and innovation. *Administrative Science Quartlery, 35*, 128-152. doi:10.2307/2393553

Crawford, L. (2005). Senior management perceptions of project management competence. *International Journal of Project Management, 23*, 7-16. doi:10.1016/j.ijproman.2004.06.005

Dahlin, K. B., Weingart, L. R., & Hinds, P. J. (2005). Team diversity and information use. *Academy of Management Journal, 48*, 1107-1123. doi:10.5465/AMJ.2005.19573112

de Wit, A. (1988). Measurement of project success. *International Journal of Project Management, 6*(3), 164-170. doi:10.1016/0263-7863(88)90043-9

DeStatis. (2015). Studierende an Hochschulen - Fächersystematik [University students - classification of study programs]. Retrieved from https://www.destatis.de/DE/Methoden/Klassifikationen/BildungKultur/StudentenPruefungsstatistik.pdf?__blob=publicationFile

Eid, M., Lischetzke, T., & Nussbeck, F. W. (2006). Structural equation models for multitrait-multimethod data. In M. Eid & E. Diener (Eds.), *Handbook of multimethod*

measurement in psychology (pp. 283-299). Washington, DC: American Psychological Association.

Heidemeier, H., & Moser, K. (2009). Self-other agreement in job performance ratings: A meta-analytical test of a process model. *Journal of Applied Psychology, 94*, 353-370. doi:10.1037/0021-9010.94.2.353

Hoever, I. J., van Knippenberg, D., van Ginkel, W. P., & Barkema, H. G. (2012). Fostering team creativity: Perspective taking as key to unlocking diversity's potential. *Journal of Applied Psychology, 97*, 982-996. doi:10.1037/a0029159

Homan, A. C., van Knippenberg, D., van Kleef, G. A., & De Dreu, C. K. W. (2007). Bridging faultlines by valuing diversity: diversity beliefs, information elaboration, and performance in diverse work groups. *Journal of Applied Psychology, 92*, 1189-1199. doi:10.1037/0021-9010.92.5.1189

Luan, K., Ling, C.-D., & Xie, X.-Y. (2016). The nonlinear effects of educational diversity on team creativity. *Asia Pacific Journal of Human Resources, 54*, 465-480. doi:10.1111/1744-7941.12078

Muthén, L. K., & Muthén, B. O. (1998-2012). *Mplus user's guide*. Los Angeles, CA: Muthén & Muthén.

National Center for Education Statistics. (2010). Introduction to the classification of instructional programs: 2010 Edition (CIP-2010). Retrieved from https://nces.ed.gov/ipeds/cipcode/contact.aspx?y=55

Nightingale, P., & Scott, A. (2007). Peer review and the relevance gap: ten suggestions for policy-makers. *Science and Public Policy, 34*, 543-553. doi:10.3152/030234207X254396

Pennington, D. (2015). A conceptual model for knowledge integration in interdisciplinary teams: orchestrating individual learning and group processes. *Journal of Environmental Studies and Sciences, 6*, 300-312. doi:10.1007/s13412-015-0354-5

Rafols, I. (2014). Knowledge integration and diffusion: Measures and mapping of diversity and coherence. In Y. Ding, R. Rousseau, & D. Wolfram (Eds.), *Measuring scholarly impact: Methods and practice* (pp. 169-190). Cham, Switzerland: Springer International Publishing.

Rosseel, Y. (2012). lavaan: an R package for structural equation modeling. *Journal of Statistical Software, 48*, 1-36. doi: 10.18637/jss.v048.i02

Steinheider, B. (2012). *Knowledge integration in research-practitioner collaborations*. Paper presented at the Science of Team Science Conference, Chicago, Il.

Steinheider, B., Bayerl, P. S., Menold, N., & Bromme, R. (2009). Entwicklung und Validierung einer Skala zur Erfassung von Wissensintegrationsproblemen in interdisziplinären Projektteams (WIP) [Development and validation of a scale for knowledge integration problems in interdisciplinary teams]. *Zeitschrift für Arbeits- und Organisationspsychologie, 53*, 121–130. doi:10.1026/0932-4089.53.3.121

Sung, N. S., Gordon, J. I., Rose, G. D., Getzoff, E. D., Kron, S. J., Mumford, D., . . . Kopell, N. J. (2003). Educating future scientists. *Science, 301*, 1485. doi:t10.1126/science.10866133

U.S. census bureau Ryan, C. (2012). Field of degree and earnings by selected employment characteristics: 2011. Retrieved from https://www.census.gov/prod/2012pubs/acsbr11-10.pdf

Valls, V., González-Romá, V., & Tomás, I. (2016). Linking educational diversity and team performance: Team communication quality and innovation team climate matter. *Journal of Occupational and Organizational Psychology, 89*, 751-771. doi:10.1111/joop.12152

van Knippenberg, D., De Dreu, C. K. W., & Homan, A. C. (2004). Work group diversity and group performance: An integrative model and research agenda. *Journal of Applied Psychology, 89*, 1008–1022. doi:10.1037/0021-9010.89.6.1008

Webber, S. S., & Donahue, L. M. (2001). Impact of highly and less job-related diversity on work group cohesion and performance: A meta-analysis. *Journal of Management, 27*, 141-162. doi:10.1016/S0149-2063(00)00093-3

Williams, K. Y., & O'Reilly, C. A. (1998). Demography and diversity in organizations: A review of 40 years of research. *Research in Organizational Behavior, 20*, 77-140.

How Interdisciplinary are Interdisciplinary Study Programs?

On the Importance of Synthesis of Knowledge for Positive Study Outcomes

Anna M. Claus and Bettina S. Wiese

Author Note: Correspondence concerning this manuscript should be addressed to Anna M. Claus, RWTH Aachen University, Institute of Psychology, Jaegerstrasse 17–19, 52056 Aachen, Germany, email: anna.claus@psych.rwth-aachen.de

Abstract

The number of interdisciplinary study programs has increased in recent decades, as interdisciplinary education is assumed to foster innovation and change for societal, technical, and environmental problems. Integration or synthesis of knowledge is a defining characteristic of interdisciplinarity and a complex task for students in interdisciplinary study programs. Organizational means and integrative curricula have been designed to support students in creating synthesis of knowledge. Here, we report on two studies that examine students' perception of synthesis of knowledge in their study programs and study outcomes. Study 1 (N = 306) included students currently enrolled in an interdisciplinary study program at diverse universities. Perceived synthesis of knowledge in the study program was associated with more positive study outcomes. This relationship was mediated by social integration with faculty and peers. Study 2 focused on one university, which allowed us to link actual curricula with students' perceptions of interdisciplinarity (N = 2,891 in 58 study programs). Interactions with faculty and peers as well as academic development mediated the effect from perceived synthesis of knowledge on study satisfaction, dropout intentions, and fulfillment of academic achievement expectations. This research provides insights into students' perceptions and success in interdisciplinary study programs. Moreover, it points to practical implications for developing and evaluating interdisciplinary study programs.

Keywords: Interdisciplinary study programs, Higher education, Synthesis of knowledge, Study outcomes

How Interdisciplinary Are Interdisciplinary Study Programs? On the Importance of Synthesis of Knowledge for Positive Study Outcomes

Interdisciplinarity aims for innovation by attending to complex problems that cannot be adequately addressed by a single discipline alone (Sung et al., 2003). Therefore, higher education programs include interdisciplinary perspectives in their curricula. In the U.S., the number of interdisciplinary degree-granting programs has more than doubled in recent decades (Brint, Turk-Bicakci, Proctor, & Murphy, 2009). As a result, an increasing population of students has studied more than one disciplinary field (Miller & Boix-Mansilla, 2004).

Students enroll in interdisciplinary study programs not only to compare different approaches and perspectives but also with the desire to work on societal, technological, or environmental problems that cross disciplinary borders (Armstrong, 1980). To effectively tackle such complex problems, students need to integrate knowledge from different disciplinary domains and create intellectual synthesis. Synthesis of knowledge is interdisciplinary integration on the organizational level of study programs (Armstrong, 1980; Spelt et al., 2009). Interdisciplinary study programs vary considerably in their curricular and organizational structure (Knight, Lattuca, Kimball, & Reason, 2013) and also in how they approach synthesis of knowledge. Some programs are organized around an overarching topic (e.g., energy, Europe). Other programs embed courses for integration and reflection of disciplinary perspectives (e.g., student portfolio class, Augsburg, 2003; constructively aligned courses, Spelt, Luning, van Boekel, & Mulder, 2015). However, some interdisciplinary study programs do not address the issue of knowledge integration in their curricula at all. Consequently, they should be considered multidisciplinary instead (Spelt et al., 2009), as the programs are additive, not integrative.

Students of interdisciplinary study programs want to work across disciplinary boundaries and expect to be educated interdisciplinarily—that is, with a high degree of integration of different disciplines (Godemann, 2006). In Study 1, we examine how students'

reports of their program's synthesis and their experiences of being socially integrated in the study program's community (contact with peers and faculty members) affect study outcomes (e.g., satisfaction, dropout intentions). Study 2 extends this approach to the synthesis of knowledge by (a) additionally including data from document analysis (written curricula) and interviews with academic counselors and (b) addressing students' expectations regarding the interdisciplinarity in their study program.

Our studies contribute to the understanding of success and satisfaction in interdisciplinary study programs, a field that has accumulated relatively little research (Spelt et al., 2009). It will shed light on whether interdisciplinary study programs match students' expectations and deliver the promises of an interdisciplinary degree. The results will prove valuable to universities and study program managers as well as to current and prospective students in interdisciplinary study programs. In addition, our results contribute to research in higher education because interdisciplinarity as a feature of study programs is a neglected topic, yet a common occurrence with relevance for various study outcomes.

Interdisciplinarity in Higher Education

Academic disciplines have evolved over many centuries from the ancient arts to today's sciences (Becher & Trowler, 2001). Academic disciplines are defined by a system of knowledge and methods but also by a specific community, journals, topics, and concepts that are unique to each discipline. The increasing complexity of the world and the sheer amount of knowledge that has evolved in past centuries give rise to specialization and a differentiation of sub-disciplines that gradually gain independence (Becher & Trowler, 2001). At the same time, however, the grand challenges of today cross disciplinary borders and require more than one discipline for significant progress. Here, interdisciplinary endeavors are expected to provide new insights.

Interdisciplinary study programs are on the rise. They are expected to prepare students for jobs at the border of disciplinary boundaries. As academic disciplines are often not aligned

with societal, technical, and environmental issues, study programs that approach certain topics and phenomena from different disciplinary perspectives aim at providing their graduates with specific skills to tackle these problems.

According to the theoretical framework for interdisciplinarity in higher education by Spelt et al. (2009), students' ability for knowledge integration and interdisciplinary thinking depend on three components: student characteristics, learning environment, and learning process. Students bring prior experiences and skills into the study program. The learning environment describes situational characteristics in interdisciplinary study programs such as teaching formats and assessment methods. The learning process itself is influenced by both student and environment and refers to specific learning activities. While the review by Spelt et al. (2009) referred to some studies that have focused on either component (e.g., curiosity as a student characteristic, Bruce, Lyall, Tait, & Williams, 2004; and balance between disciplinarity and interdisciplinarity, Newell, 1992), there were no studies that link students, study programs, and study outcomes. This clearly is a research gap to be closed given that the interplay between characteristics of students and learning environments is the core of Spelt et al.'s (2009) theoretical approach. It is this interplay that is expected to explain successful outcomes of interdisciplinary study programs.

Taking a closer look at different interdisciplinary study programs as learning environments, many programs consist of a collection of courses that stem from different disciplines and relate to the program (e.g., Women's Studies, American Studies; see also Sill, 1996). But connections between the different courses are not explicitly addressed, so interdisciplinary integration is (at least formally) not guided by faculty members and has to be created by the students themselves (or not at all). Sill (1996) describes these programs as tag team programs and points out that their nature is rather multidisciplinary (i.e., a juxtaposition of disciplines Repko et al., 2014) due to the lack of integration between the different disciplines. Knight et al. (2013) examined interdisciplinary liberal arts programs and found

significant variation regarding the organizational and curricular features of the programs. In other words, some but surely not all interdisciplinary study programs keep their integrative promise.

Levels of Integration and Synthesis of Knowledge

Armstrong (1980) differentiates four levels of intellectual integration and synthesis of knowledge in study programs. The simplest case of interdisciplinarity in study programs is for students "to take a selection of the normal disciplinary offerings from more than one discipline" (p. 53). However, this might be the least effective approach as the interdisciplinary synthesis is left with the student. The second level enables students to meet with their peers to discuss synthesis, for example within a capstone seminar. The third level is characterized by faculty members sharing their disciplinary perspectives on an issue in a serial way, for example in a lecture series. The highest level of interdisciplinary synthesis attempts to create a new coherent entity based on integration of various fields of knowledge and true team teaching. Lindvig and Ulriksen (in press) use three different metaphors to demonstrate how interdisciplinary integration can be achieved in teaching: Pearls on a string refer to serial teaching of disciplinary perspectives, the zipper underlines that someone (oftentimes the student) has to tie different disciplinary elements together, and the snowflake organizes different disciplinary perspectives around a common theme or method in the center. Here, the idea is that there is no hierarchy between those three conceptions, but rather that each caters for certain purposes and has individual strengths and weaknesses (Lindvig & Ulriksen, in press).

Interdisciplinary study programs can support students in knowledge integration by addressing synthesis of knowledge in their curricula. In this regard, interdisciplinary study programs differ significantly from each another. Some study programs organize their curricula around an overarching topic (such as Europe or energy), which eases knowledge integration as different theories and methods can be linked directly to the topic of the study

program. In study programs that are more additive in nature (i.e., students take courses offered by different departments), knowledge integration can be achieved using bridging courses and portfolio classes (Augsburg, 2003). Students' perceptions of the intellectual synthesis of their study programs can be more or less directly linked to these organizational means of creating knowledge integration.

Meeting Students' Expectations

Students expect interdisciplinary program synthesis of an interdisciplinary study program: "[…] students may have come to their education with a desire to grapple with some pressing societal problem, only to find that to do so effectively requires a more holistic approach […]" (Armstrong, 1980, p. 52). A holistic interdisciplinary approach and a high level of interdisciplinarity require integration of knowledge from different disciplinary fields to create intellectual synthesis of disciplinary perspectives. Klein and Newell (1996) emphasize that knowledge integration is an important requirement for both faculty members and students in interdisciplinary study programs. Connecting diverse bodies of knowledge is particularly difficult for students, as they usually lack an established understanding of one discipline compared to faculty members. Hence, students need assistance in developing a comprehensive understanding of the interdisciplinary synthesis and interconnections between disciplines: "students shall not be expected to integrate anything the faculty can't or won't" (Gaff, 1980, p. 54).

Meeting the expectations of students regarding the degree of interdisciplinarity is associated with positive study outcomes (Smith & Wertlieb, 2005). Students who expect a holistic education in an interdisciplinary study program might be disappointed when faced with an additive program and therefore be less satisfied with their studies (Minnis & John-Steiner, 2005). In cases of severe mismatch of expectations and reality, dropout intentions might rise.

Study 1

Study 1 investigated the relationship between perceived synthesis of knowledge in the study program and study satisfaction and dropout intentions. We expected that students who perceived their study programs as interdisciplinarily integrated would be more content and might be in a better position to fulfill their academic potential. Consequently, we postulated the following hypotheses:

Hypothesis 1: Synthesis of knowledge in study programs is positively related to study satisfaction.

Hypothesis 2: Synthesis of knowledge in study programs is associated with lower dropout intentions.

Hypothesis 3: Synthesis of knowledge in study programs is positively associated with fulfillment of academic expectations.

Success and retention in a study program also depend on social aspects. Tinto (1993) describes social integration with peers and faculty members as an important factor for students in their commitment and success in higher education. Looking at interdisciplinary study programs, we argue that programs that require students to take classes offered by different departments make social integration more difficult for students. As they meet different peers in every class, a sense of being part of a group and interactions with fellow students might not develop as easily as in monodisciplinary programs. Furthermore, faculty members might prefer to spend their time interacting with students who chose their respective discipline as a major and might allocate fewer resources on students who are enrolled in an interdisciplinary program. Less contact with peers and faculty in turn are associated with a higher risk of dropout and decreased subjective and objective study success (Dahm, Lauterbach, & Hahn, 2016). Perceived synthesis of knowledge can help students to create a holistic image of their study program—not only as an academic system but also as a social system with a peer group and faculty. From a constructivist point of view, this socio-

intellectual conceptualization of the study program builds the basis for meaningful interactions with peers and faculty members, which are known to have positive effects on study success. This leads to *Hypothesis 4: The effects of synthesis of knowledge in study programs on study satisfaction, drop out intentions, and fulfillment of academic expectations are mediated by social integration with peers and faculty members.*

Method

We conducted an online study with students who were currently enrolled in an interdisciplinary study program at institutions for higher education in Germany to test our hypotheses.

Sample.

The sample consisted of $N = 306$ students (58.2% women) who were currently enrolled in an interdisciplinary study program. The students were on average 23 years old; 66.3% were pursuing a bachelor's degree, and 33.3% were pursuing a master's degree. Most students attended public universities (79.1%), followed by universities of applied sciences (17.6%). Students were enrolled in various study programs covering different disciplinary fields such as industrial engineering (24.2%), health economy (10.1%), chemical engineering (3.6%), and international relations (2.3%). Only 19.0% of students reported that their study program had an overarching topic such as "Europe," "simulation," or "corruption." Regarding the structure and organization of the study programs, 59.8% of students typically attended classes that were offered for students of other study programs, and only 7.5% reported that classes were exclusively offered for their respective study programs.

Instruments.

Perceived synthesis of knowledge in the study program was measured by four items created by the authors. Item wording was checked for face validity and revised within the team. A pretest with 114 (58.0% women) yielded a stable factor structure for a four-item scale. Items were "In my study program, the synthesis of different disciplines is openly

discussed," "My study program closely connects different disciplines," "Due to the interdisciplinarity of my study program, I am able to consider a problem from different disciplinary perspectives," and "In my study program, it is important to take different perspectives on a task." The internal consistency of the scale was satisfactory (α = .74).

The outcome variables were operationalized with short versions of scales used in the National Education Panel Study (NEPS; Dahm et al., 2016). *Study satisfaction* was measured by three items from the affective involvement subscale of the Academic Commitment Scale (e.g., "I enjoy my field of studies very much"; Grässmann, Schultheiss, & Brunstein, 1998; α = .80) . To measure whether *students' academic achievement expectations* were met, we used three items from the Fulfillment of Achievement Expectations Scale (Trautwein et al., 2007). An example item is, "I am satisfied with my performance in the degree program" (α = .64). Regarding dropout intentions, three items from the study by Trautwein et al. (2007) were employed (e.g., "I often think about dropping out"; α = .60).

Social integration was operationalized in accordance with Dahm et al. (2016), who created scales with four items each for interactions with faculty (e.g., "I get along well with the instructors in my degree program"; α = .87) and fellow students (e.g., "I have been successful in building contacts with other students during my studies"; α = .89). See Table 1 for scale correlations.

Analytical approach.

In order to test the hypotheses, we used path analyses using the Mplus software. Path analyses allow us to simultaneously study several dependent variables such as different study outcomes. The models were saturated models with no degrees of freedom and thus no fit indices.

Table 1

Study 1: Descriptive statistics and bivariate correlations

	Construct	*M*	*SD*	1	2	3	4	5	6
1	Perceived synthesis of knowledge	3.50	.77	.74	.47**	.28**	-.21**	.34**	.16**
2	Study satisfaction	3.57	.87	.47**	.80	.53**	-.58**	.55**	.32**
3	Fulfillment of achievement expectations	3.56	.77	.28**	.53**	.64	-.43**	.37**	.33**
4	Dropout intentions	1.68	.79	-.21**	-.58**	-.43**	.60	-.34**	-.23**
5	Interactions with faculty	3.71	.84	.34**	.55**	.37**	-.34**	.87	.21**
6	Interactions with peers	3.70	1.02	.16**	.32**	.33**	-.23**	.21**	.89

Note. Internal consistencies are shown in the diagonal. $N = 306$; ** $p < .01$

Results

First, we studied how perceived synthesis of knowledge in the study program was associated with subjective study outcomes (*Hypotheses 1–3*). As expected, program synthesis was a significant predictor for study satisfaction ($b = .53$; $p < .001$), dropout intentions ($b = -.21$; $p < .001$), and fulfillment of achievement expectations ($b = .28$; $p < .001$; see Figure 1). Perceived synthesis of knowledge in the study program explained significant variance in study satisfaction ($R^2 = .22$; $p < .001$) and fulfillment of achievement expectations ($R^2 = .08$; $p < .01$) but not in dropout intentions ($R^2 = .04$; $p = .07$).

Second, social integration with faculty and fellow students were included as mediators in the model (*Hypothesis 4*; see Figure 2). Interactions with faculty and peers partially mediated the effect of perceived synthesis of knowledge in the study program on study satisfaction and fulfillment of achievement expectations. There was a full mediation of interactions with faculty and peers for the effect of disciplinary synthesis on dropout intentions. The explained variance in the outcomes was substantial for study satisfaction

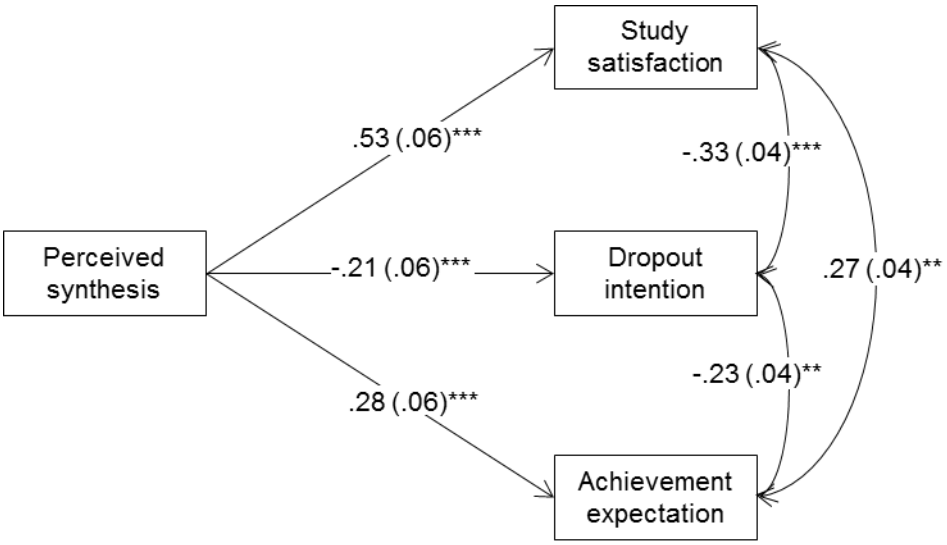

Figure 1. Study 1: Pathmodel of the effects of perceived synthesis of knowledge in the study program on study outcomes. *SE* in parenthesis. *** $p < .001$; ** $p < .01$

($R^2 = .43$; $p < .001$). For dropout intentions ($R^2 = .14$; $p < .001$) and fulfillment of achievement expectations ($R^2 = .22$; $p < .001$), explained variance was moderate. Perceived disciplinary synthesis explained 11.8% of variance in social integration with faculty ($p < .001$) but not a significant amount of variance in social integration with fellow students ($R^2 = .03$; $p = .16$). The total effect from perceived synthesis of knowledge in the study programs on study satisfaction was significant according to the Sobel test ($z = .53$; $p < .001$), as were the indirect effects (total indirect effect = .19; $p < .001$) and the direct effect (.34; $p < .001$). The total effect from perceived synthesis of knowledge on dropout intentions was significant (-.21, $p < .001$); however, the indirect effect via social integration with peers (-.03; $p = .05$) and the direct effect (-.09; $p = .12$) were not significant. Hence, the full mediation of perceived disciplinary synthesis on dropout intentions was due to interactions with faculty (specific indirect effect = -.09; $p < .001$). The total effect of perceived synthesis of knowledge in the study programs on fulfillment of achievement expectations was significant (.28; $p < .001$), as were the indirect effects (total indirect effect = .13; $p < .001$) and the direct effect (.16; $p < .01$).

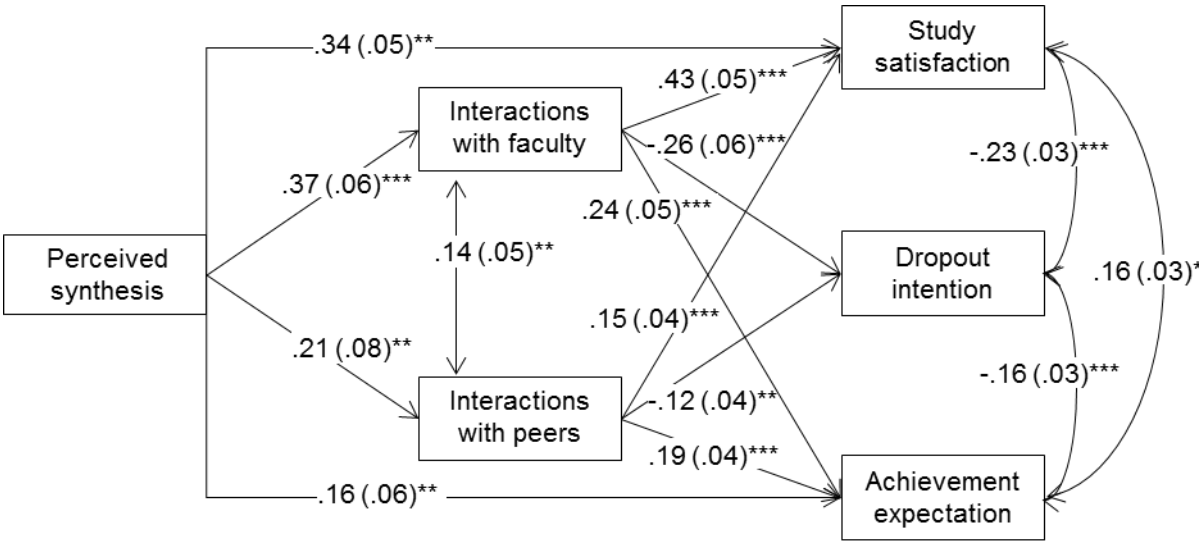

Figure 2. Study 1: Pathmodel including interactions with faculty members and fellow students as mediators of the effect of perceived synthesis of knowledge in the study program on study outcomes. *SE* in parenthesis. *** $p < .001$; ** $p < .01$

Discussion

Our study shows that perceived synthesis of knowledge in a study program is associated with higher study satisfaction, higher fulfillment of achievement expectations, and lower dropout intentions. Consequently, students' perceptions regarding the organization of their study program matters for their study success. As integration of knowledge between disciplinary perspectives is particularly important for a holistic study experience in interdisciplinary study programs, perceived synthesis of knowledge is closely connected with students' satisfaction. Students' perception of their study programs regarding integrating diverse bodies of knowledge also mattered for their ability to use their academic potential and fulfill their own achievement expectations. Regarding dropout intentions in interdisciplinary study programs, the picture is less clear, as there was an association between perceived synthesis and dropout intentions, but only little variance in dropout intentions could be explained. Considering dropping out of an academic study program can have many causes, and some of them are not specific to interdisciplinary study programs (e.g., lack of interest, ability-requirement mismatch).

In addition, we found the relationships between perceived study program synthesis and study outcomes to be partially explained by interactions with faculty and fellow students. Furthermore, our results indicate that social integration is relevant in study programs that are more additive in nature; interactions with faculty and, to a lesser degree, interactions with peers can ensure that low perceived connectedness of disciplines does not have harmful side effects.

Study 1 employed solely self-report measures. While self-reports are adequate to measure satisfaction and perception of students, the design of study programs and the disciplinary synthesis of knowledge might be experienced differently by students in the same program. Here, the curricular regulations and program requirements could serve as a more objective measure of knowledge integration in the respective program.

Study 2

Study 2 further develops the key findings of Study 1 in several ways. First, we examine how students' perception of synthesis of knowledge in their study program arises and can be shaped by organizational measures. According to Armstrong's (1980) taxonomy of intellectual synthesis, certain teaching formats are particularly helpful in aiding students to gain integrated knowledge. Thus, we arrive at *Hypothesis 5: Integrative teaching formats (capstone seminars, interdisciplinary lecture series, team-taught courses, and the like) lead to higher perceived synthesis of knowledge.*

Second, we extend our model to include academic integration as well. Tinto (1993) states that retention and success in higher education depend, among other things, on positive social and intellectual experiences in the respective institution. While social integration refers to having interactions with students and faculty members to find a community and a sense of belonging, academic integration aims at the intellectual development of the students. Study programs require students to grow intellectually, to learn, and to fulfill formal obligations. In Tinto's (1993) model, integration into the academic world of universities is ascribed an

important role for study retention. We apply this idea to interdisciplinary study programs, which can pose specific intellectual challenges on students—for example, in terms of disciplinary integration. In the same vein, students who have positive academic experiences should find it easier to come to terms with their study program and to successfully complete their degree.

Hypothesis 6: Social and academic integration mediate the effect of perceived synthesis of knowledge in the study program on study satisfaction, dropout intentions, and fulfillment of academic achievement expectations.

Third, students' expectations regarding the interdisciplinarity of the study program must be considered. Interdisciplinary study programs vary severely, as is the extent to which the program's interdisciplinarity is advertised to prospective students. Perceived program synthesis should influence study outcomes particularly if students had hopes and expectations about high interdisciplinarity in the study program. Disappointed expectations in this regard should negatively impact study satisfaction and increase dropout intentions.

Hypothesis 7: The effect of perceived synthesis of knowledge in the study program on study outcomes is moderated by the extent to which experiences meet expectations regarding the interdisciplinarity of the study program.

Method

Study 2 was conducted at one large university in Germany. By focusing on one institution, we were able to directly link curricula and program requirements regarding the synthesis of knowledge to students' perception of interdisciplinarity.

At that university, 175 study programs are offered. The online descriptions of the study programs stated that 58 programs are interdisciplinary (33.1%; e.g., data science, material science, mobility and traffic). The other programs are either clearly monodisciplinary

(e.g. chemistry, psychology) or aim at a teaching degree.[10] We include all programs that are advertised as being interdisciplinary in our study, although some are clearly multidisciplinary (i.e., they juxtapose disciplinary perspectives and do not attempt to integrate them).

As a first step, we studied the curricula and program requirements of all 58 interdisciplinary study programs (24 bachelor's and 34 master's programs) closely, looking for indications of synthesis of knowledge in the study programs. As not all possible features of intellectual synthesis in interdisciplinary studies can be found in curricula and program requirements (for example team-teaching, see also Knight et al., 2013), we interviewed the academic counselors of the study programs (N = 26; some counselors are responsible for more than one study program). In the interviews, we inquired about different aspects of interdisciplinary integration and asked what makes each study program interdisciplinary (see appendix for interview manual).

We combined a deductive approach based on the model of Armstrong (1980) with an inductive approach. Based on the model, the coding scheme for interdisciplinary synthesis of knowledge includes the following model categories: selection of normal disciplinary offerings from more than one discipline, capstone seminars, interdisciplinary lecture-series, team teaching, and true interdisciplinary courses created for a program. Based on the documents and interviews with the academic counselors of the study programs, we added specific categories that were considered intensely integrative. The added categories were lab studies, simulation games, integrative colloquia, field projects, and integration of practitioners in teaching interdisciplinary practices (see Table 2). Finally, all study programs were rated on whether they incorporated each criterion. On average, programs incorporated 2.83 out of 10 potential criteria (range 1 to 7).

[10] We argue that integration of disciplinary perspectives is less relevant for teaching degrees—for example, studying mathematics and biology for a teaching degree would rarely require combining disciplinary perspectives of math and biology.

Table 2

Coding scheme for interdisciplinary synthesis of knowledge based on curricula and program requirements as well as interviews with the respective academic counselors

No.	Criterion	No. offering	Example
1	Selection of normal disciplinary offerings from more than one discipline*	56	Courses are offered from both an engineering science and business and economics
2	Capstone seminars*	0	[not offered]
3	Interdisciplinary lecture-series*	30	Researchers from different departments present their perspective on communication and technology
4	Team-teaching*	2	An engineer, a biologist and a medical researcher offer a course on transplants for students of biomedical engineering
5	True interdisciplinary courses created for program*	10	Course on sociotechnical changes combining approaches from sociology, natural sciences and engineering for students of environmental engineering
6	Lab studies	10	Students perform lab experiments that combine tasks and knowledge from electrical engineering and information science
7	Simulation games	5	Simulation of a project on material and energy laws which requires to combine both technical and legal knowledge
8	Integrative colloquia	11	Students present their theses which were advised by researchers from different departments
9	Field and research projects	19	Projects on speech, cognition, and usability in communication science study program
10	Interdisciplinary practitioners	22	Some courses are taught by employees of a Christian development aid organization for students who study theology and global development

Notes: * Criteria are based on the model of interdisciplinary integration by Armstrong (1980). There were no capstone seminars offered in the 58 study programs in our study.

In a second step, students of the respective study programs were invited to participate in an online survey of their experiences with interdisciplinarity in their study programs.

Sample.

At the time of measurement, there were 14,850 students registered in the 58 interdisciplinary study programs at the respective university (range 7 to 2,143 per program). We emailed all of them and asked them to participate in a short online survey. Our sample consists of N = 2,891 students (36.7% women; overall response rate = 17.4%; range 8.9% to 71.4% per program). Most students were enrolled in a bachelor's program (55.8%).

Instruments.

For most measures, the same scales were used as in Study 1. *Perceived disciplinary program synthesis of knowledge* was again measured by four self-developed items. The internal consistency of the scale was good (α = .81). We measured *expectations of studies regarding interdisciplinarity* with one item ("My study experiences meet my expectations regarding the interdisciplinarity of the study program"; based on Thiel, Blüthmann, & Richter, 2010).

Study satisfaction was measured with five items from the satisfaction with study-contents scale by Schiefele and Jacob-Ebbinghaus (2006). An example item is, "I very much enjoy my studies" (α = .90). To measure *whether students' achievement expectations have been met*, we again used three items from the Fulfillment of Achievement Expectations Scale (Trautwein et al., 2007; α = .88). Regarding *dropout intentions*, again five items from the study by Trautwein et al. (2007) were employed (α = .77).

Social integration was once more operationalized using the scales of Dahm et al. (2016). We used four items for interactions with faculty (α = .87) and three items for interactions with fellow students (α = .91). As a measure of *academic integration*, we included the three item-subscale academic and intellectual development of the Institutional

Table 3

Study 2: Descriptive statistics and bivariate correlations

	Construct	*M*	*SD*	1	2	3	4	5	6	7	8	9
1	Perceived synthesis of knowledge	3.68	1.08	.81								
2	Expectations of studies	4.22	.95	.45**	.78							
3	Study satisfaction	4.37	1.16	.43**	.63**	.90						
4	Fulfillment of achievement expectations	3.49	1.34	.18**	.30**	.37**	.88					
5	Dropout intentions	1.96	1.01	-.26**	-.43**	-.61**	-.28**	.77				
6	Interactions with faculty	4.43	1.05	.39**	.50**	.49**	.27**	-.34**	.87			
7	Interactions with peers	4.16	1.46	.21**	.30**	.35**	.29**	-.26**	.27**	.91		
8	Faculty concern for student development	4.07	.99	.32**	.34**	.37**	.19**	-.26**	.68**	.19**	.75	
9	Academic development	4.68	1.01	.33**	.51**	.78**	.26**	-.52**	.44**	.29**	.39**	.77

Note. Internal consistencies are shown in the diagonal. N = 2891; ** p < .01

Integration Scale (e.g., “I am satisfied with the extent of my intellectual development since enrolling in this university”; α = .71; Pascarella & Terenzini, 1980).

Furthermore, as more objective measures, we included self-reported average grades and credit points earned. In the German grading system, the best grade is a 1.0 and the last passing grade is a 4.0, hence lower numbers represent better grades. Full-time study programs in Germany usually entail 30 credit points to be earned per semester. We calculated the average credit points earned per semester for each student based on their reported semesters in the respective study program to represent study progress. See Table 3 for scale correlations and descriptive statistics.

Analytical approach.

As students are nested in their study programs, the dataset has a multilevel structure. We accommodate the interdependencies within the study programs by employing multilevel models (also called hierarchical linear models or mixed-effects models). The analyses are carried out using the R package lavaan (Rosseel, 2012). For the constructs measured by scales (perceived program synthesis, study satisfaction, fulfillment of academic achievement expectations, dropout intention, social integration with faculty and peers, and academic and intellectual development), we used a factor score approach (Devlieger & Rosseel, 2017); each construct was modeled using a confirmatory factor analysis, and the latent variable was then saved. The saved latent variables were used like any manifest variable in further analyses. This approach enabled us to combine the advantages and properties of latent modeling with multilevel path analyses in lavaan.

Results

Due to the nested data structure, we start by examining the variance proportions on the study program level. As the study programs differ greatly regarding their structure, disciplines, etc., it is not surprising that significant variance lies at the program level; 15.0% of perceived synthesis of knowledge in the study program can be explained by the program, 3.0% of variance in study satisfaction; 4.6% of variance in dropout intentions, and 9.8% in fulfillment of academic achievement expectations. Regarding average grades, 28.0% of the variance lies at the program level, reflecting different disciplinary grading cultures. Based on these variance components, we decided to include study program variance in all our models.

Next, we were interested in studying how the indicators for program synthesis (see Table 2) affect both students' perceived synthesis and study outcomes. We included the indicators for program synthesis as predictors in a multilevel mediation model with perceived synthesis as a mediator for the effect of program synthesis indicators on subjective study outcomes (see Figure 3a). As this was a saturated model, no fit indices were available.

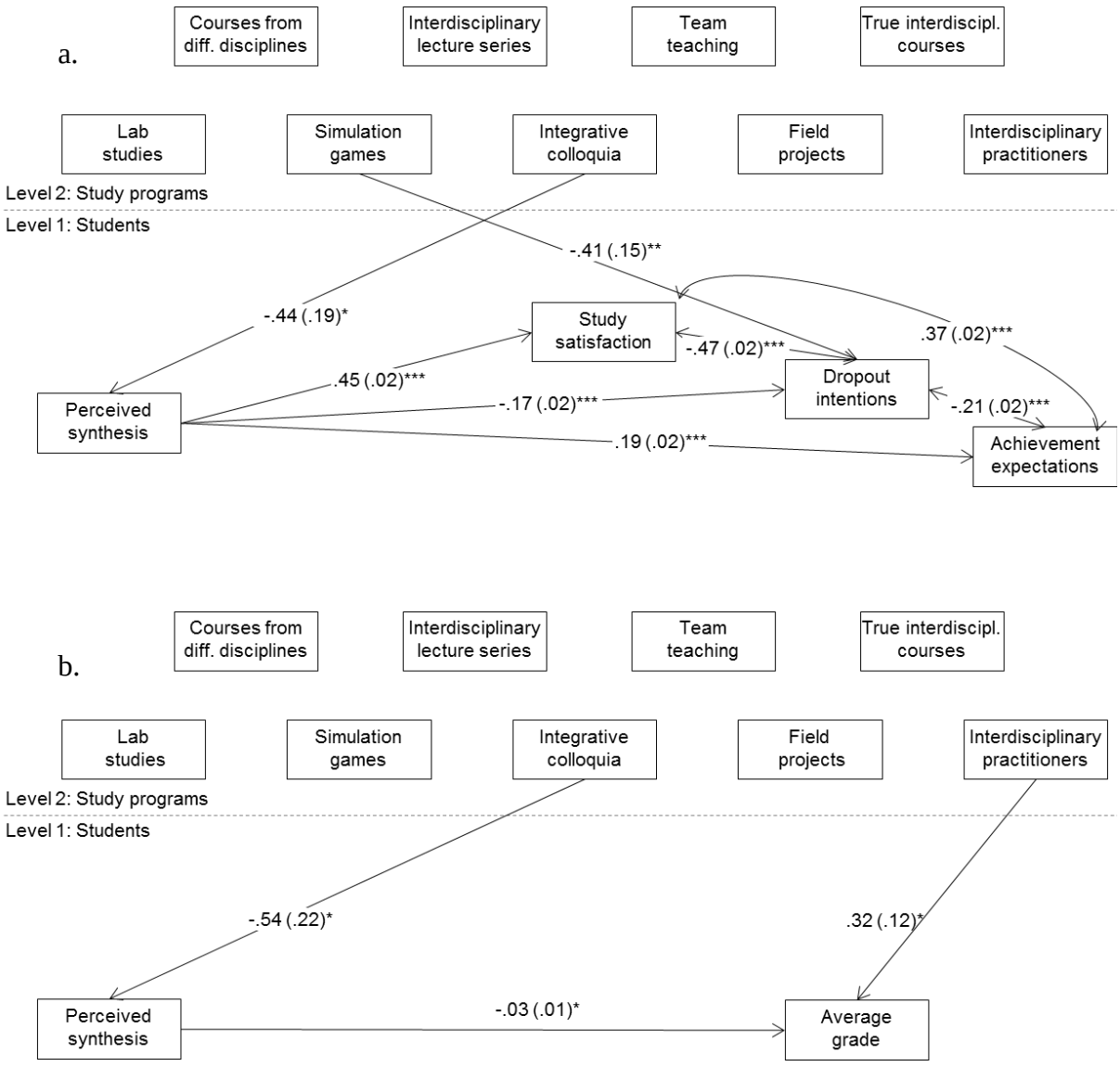

Figure 3. Study 2: Indicators of interdisciplinary synthesis of knowledge as predictors for perceived program synthesis and

a. subjective study outcomes; $N = 2581$ in 58 study programs.

b. average grade; $N = 1858$ in 57 study programs.

Saturated models. Only significant paths are shown. *SE* in parenthesis. *** $p < .001$; ** $p < .01$; * $p < .05$

Integrative colloquia were negatively related ($b = -.44$; $p < .05$) with perceived synthesis. In addition, simulation games were associated with reduced dropout intentions ($b = -.41$; $p < .01$). Perceived synthesis was associated with more positive subjective study outcomes (i.e., increased study satisfaction; $b = .45$; $p < .001$), fulfillment of academic achievement

expectations (b = .19; p < .001), and lower dropout intentions (b = -.17; p < .001). At the study program level, the entire model explains 34.0% *(*p < .001) of the variance in perceived integration, 29.8% (p < .001) of variance in study satisfaction, 50.1% (p < .001) of variance in dropout intentions, and 26.8% (p < .001) of variance in fulfillment of academic achievement expectations. At the student level, the explained variance was smaller yet significant (R^2 study satisfaction = .15; p < .001; R^2 dropout intentions = .03; p < .001; R^2 achievement expectations = .03, p < .001).

Regarding self-reported objective outcomes, study programs in which some courses were taught by interdisciplinary practitioners were positively associated with average grades of the students (b = .32; p < .05; n = 1,858; see Figure 3b), which implies an unexpected negative association with student performance. Again, integrative colloquia were negatively related with perceived program synthesis (b = -.52; p < .05). Perceived program synthesis was negatively associated with average grades (b = -.03; p < .05), which means that students who perceived their study program as more integrated had better grades. The model does not explain significant variance in the average grade (at the student level, R^2 = .00; at the study program level, R^2= .25). Study progress (i.e., the average gain in credit points per semester) was negatively related with true interdisciplinary courses (b = -.06; p <.01; n = 1,799), and there was no connection with perceived study program synthesis. Variance in study progress could not be explained by the model (at the student level, R^2 = .00; at the study program level, R^2 = .85).

To test the role of academic and social integration in interdisciplinary study programs, and according to *Hypothesis 6*, we specified a mediation model (see Figure 4) in which the effect of perceived integration on subjective study outcomes is mediated by academic development and interactions with faculty and peers ($\chi^2(13) = 669.18$; CFI = .84; RMSEA = .14). Academic development (specific indirect effect = .19; p < .001) and interactions with faculty (specific indirect effect = .07; p < .001) and peers (specific indirect

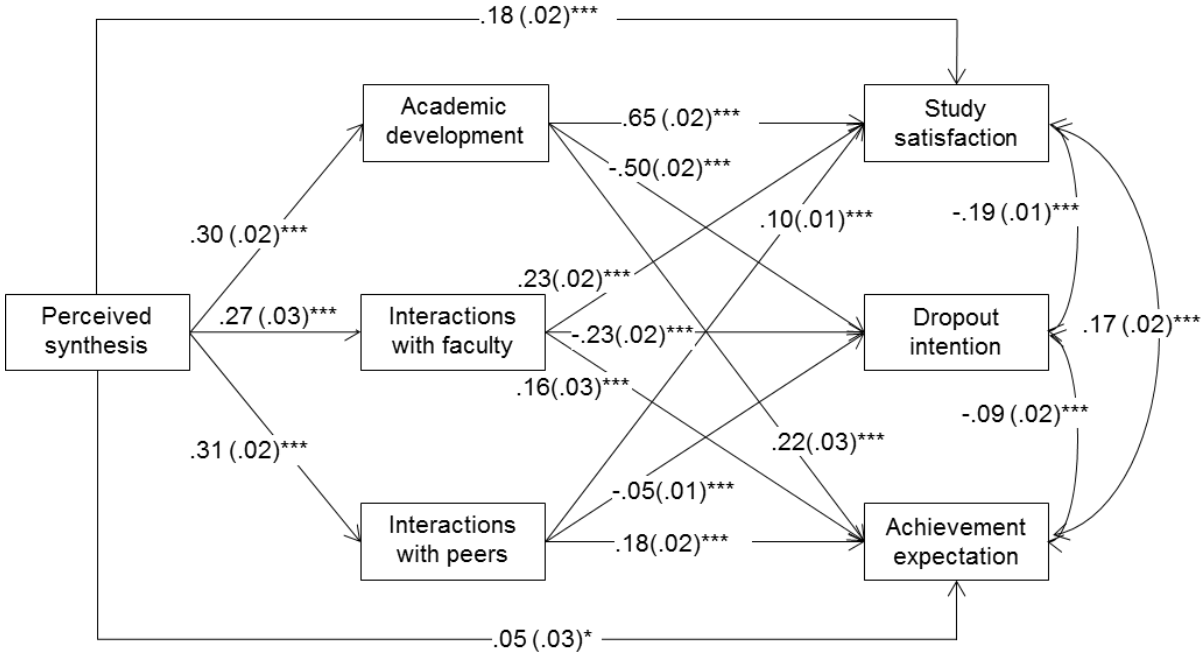

Figure 4. Study 2: Mediation of the effect of perceived synthesis of knowledge in the study program on subjective study outcomes by academic and social integration.
N = 2581 in 58 study programs. χ^2 (13) = 669.18; CFI = .84; RMSEA = .14.
Only significant paths are shown. *SE* in parenthesis. *** $p < .001$; ** $p < .01$; * $p < .05$

effect = .03; $p < .001$) partially mediated the effect of perceived integration on study satisfaction (direct effect = .18; $p < .001$; sum of indirect effects = .29; $p < .001$, total effect = .47; $p < .001$). There was a complete mediation of the effect of perceived synthesis of knowledge in the study program on dropout intention (direct effect = .02; $p = .33$) via academic development (specific indirect effect = -.15; $p < .001$), interactions with faculty (specific indirect effect = -.04; $p < .001$), and interactions with peers (specific indirect effect = -.01; $p < .001$; sum of indirect effects = -.20; $p < .001$; total effect = -.18; $p < .001$). With regard to fulfillment of academic achievement expectations, we found a partial mediation (direct effect = .05; $p < .05$) via academic development (specific indirect effect = .07; $p < .001$) and both interactions with faculty (specific indirect effect = .05; $p < .001$) and peers (specific indirect effect = .05; $p < .001$; sum of indirect effects = .17; $p < .001$; total effect = .22; $p < .001$). The model explained significant variance in study

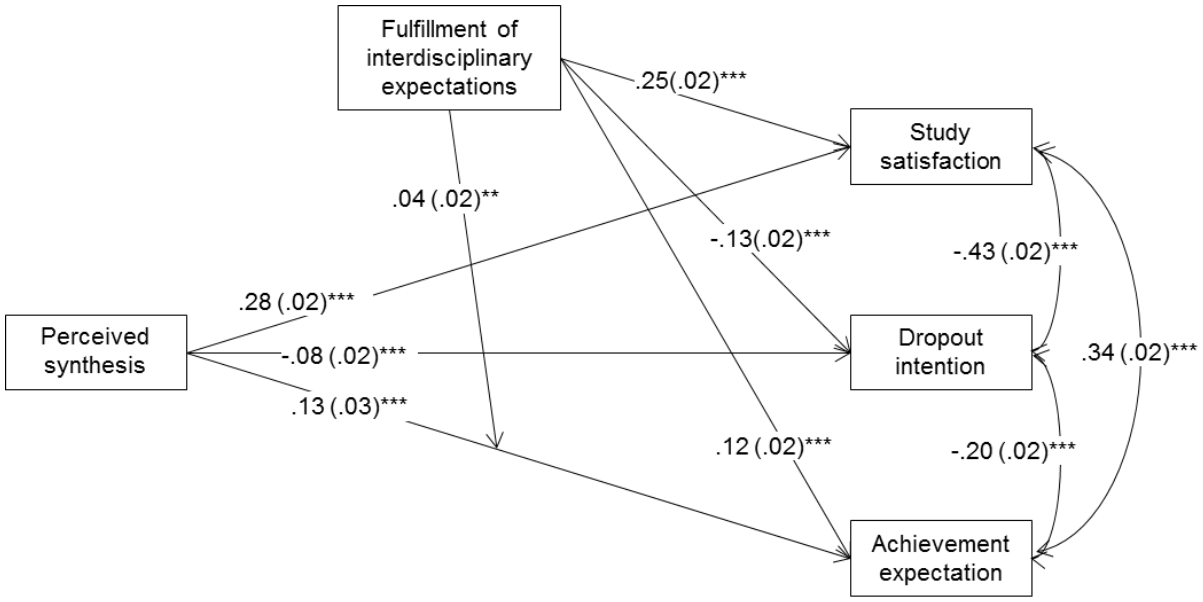

Figure 5. Study 2: Fulfillment of interdisciplinary expectations moderates the relationship between perceived synthesis of knowledge in the study program and fulfillment of academic achievement expectations.
N = 2572 in 58 study programs. χ^2 (6) = 23.84; CFI = .99; RMSEA = .03.
Only significant paths are shown. *SE* in parenthesis. *** $p < .001$; ** $p < .01$; * $p < .05$

satisfaction ($R^2 = .47$; $p < .001$), dropout intentions ($R^2 = .22$; $p < .001$), and fulfillment of achievement expectations ($R^2 = .12$; $p < .001$).

Finally, we tested whether the effect of perceived synthesis of knowledge on study outcomes was moderated by the fulfillment of students' expectations regarding interdisciplinarity in their study programs (*Hypothesis 7*; see Figure 5). This was the case for fulfillment of academic achievement expectations ($b = .04$; $p < .01$). Here, the moderator changes the path coefficient from perceived synthesis to fulfillment of academic achievement expectations from $b = .13$ ($p < .001$) for average fulfillment of expectations regarding interdisciplinarity to $b = .19$ ($p < .001$) for one standard deviation above the mean (and $b = .07$; $p < .05$; for -1 *SD* respectively). Furthermore, there were direct effects from students' expectations regarding interdisciplinarity to the study outcomes ($b = .25$; $p < .001$ for study satisfaction, $b = -.8$; $p < .001$ for dropout intentions, and $b = .12$; $p < .001$ for fulfillment of academic achievement expectations). The model explained significant variance in study

satisfaction (R^2 = .23; p < .001), dropout intentions (R^2 = .06; p < .001), and fulfillment of achievement expectations (R^2 = .05; p < .001).

Discussion

"…and that is hard to get together. We try to make clear, why they would need these components [different disciplinary courses]. The curse of the beginner is not to be able to look from the perspective of a graduate, a practitioner, an expert." (Interview 23)

Synthesis of knowledge in interdisciplinary study programs lies at the core of the idea of each interdisciplinary study program—bringing together different disciplinary perspectives, integrating them, and creating something new based on interdisciplinary thinking. However, creating opportunities for the synthesis of knowledge is a challenge for the study programs, just as knowledge integration is a challenge for the students.

The study programs in Study 2 varied greatly in the number of students enrolled, the disciplines involved in the program, and the degree of synthesis of knowledge in the study programs that allows for interdisciplinary knowledge integration. Considering variance components revealed that being enrolled in a certain study program accounted for differences in students' perception of synthesis of knowledge and for differences in study outcomes. Hence, our approach to examine students in their respective study programs proved favorable.

The results of Study 2 indicate that perceived synthesis of knowledge is not a simple function of integrative teaching formats. Although the indicators for organizational synthesis could explain significant variance in students' perceptions when taken together, the picture is not as clear for single indicators. Unexpectedly, study programs that contain integrative colloquia were linked with lower synthesis according to students. This result is counterintuitive as one might think that any organizational measure for synthesis of knowledge would be beneficial. According to Armstrong's (1980) taxonomy of intellectual synthesis of knowledge in interdisciplinary study programs, integrative colloquia would rank in one of the lower categories as colloquia often entail a serial approach of communicating

disciplinary perspectives and integration is mostly left to the students. We speculate that integrative colloquia are a relatively simple measure for an interdisciplinary teaching format and are included in some study programs that do not aim at creating a highly integrative study experience. It is noteworthy that many interdisciplinary teaching formats differ from the conventional university lecture, for instance, simulation games and field projects. Lindvig and Ulriksen (in press) argue that these formats may lie outside the comfort zone of university teachers which can limit the integrative effectiveness of the courses.

Furthermore, the question arises what factors account for the unexplained variance in perceived synthesis of knowledge, if not integrative teaching formats. Here, we conclude that other, less formalized aspects might play a role. Interdisciplinary synthesis of knowledge might also be created in courses that do not appear to be particularly integrative on paper. It is each lecturer's didactic liberty to address interdisciplinary perspectives in their courses. Broaching the issue of interdisciplinary integration can happen in any class using examples and cases that cross disciplinary borders, referring to information from courses offered by another discipline, and addressing the challenges of interdisciplinary studies in conversations. However, it is noteworthy that in the German system of higher education, there is hardly any class with compulsory attendance. Hence, students are free to choose whether to take part in integrative teaching formats for synthesis of knowledge. This might partially explain the substantial variance in perceived synthesis of knowledge also within each study program.

Most importantly, this study also highlights the necessity of academic and social integration in interdisciplinary study programs. According to Tinto's (1993) theory on student retention, feeling a sense of belonging to the university as both an academic and a social system is relevant for students' retention and success in higher education. In interdisciplinary study programs, both can be more challenging than in monodisciplinary study programs due to possible preferences of faculty members for their monodisciplinary students and lack of a constant peer group. Study 2 showed that effects of perceived synthesis of knowledge on

subjective study outcomes was partially mediated by academic development as well as interactions with faculty and peers. Students who perceive their study programs as holistic and synthesized also judged their academic development as more favorable and interact more frequently or more intensely with their peers and faculty members. This in turn explains the positive subjective study outcomes.

We argue that students who chose to enroll in an interdisciplinary study program have expectations regarding the holistic interdisciplinarity of said program (Armstrong, 1980; Godemann, 2006). Study 2 revealed that the fulfillment of students' expectations regarding the interdisciplinarity of the study program moderated the relationship between perceived synthesis of knowledge and the fulfillment of academic achievement expectations. Nevertheless, expectations also had an immediate effect on study outcomes. When expectations have been met, students evaluate their studies more positively and consider dropping out to a lesser degree. Students whose expectations have been fulfilled regarding the interdisciplinarity of the study program demonstrate a higher association between perceived synthesis and study outcomes.

Study 2 was conducted at a single university in Germany. Although certain programs might be unique to this university, most interdisciplinary programs can be found at many other institutions for higher education. However, differences in the design of study programs are quite plausible, as those were already apparent within this one university. Our approach aims at understanding the mechanisms in interdisciplinary study programs in general, and therefore results should not be limited to the institution in this study. In Germany, study programs are often quite rigorously defined and planned with detailed curricula and program requirements. This might limit the generalizability of the results to study programs in which students freely choose their own studies (e.g., liberal arts programs, see Knight et al., 2013). In addition, Study 2 did not take timing into account. Some integrative teaching formats might be scheduled for students in higher semesters (as would be the case for capstone seminars), so

first-year students could not include this experience in their perception and evaluation of their study programs.

General Discussion

We set out to examine how interdisciplinary study programs are designed to fulfill their promise of interdisciplinarity in a sense of integrating different disciplinary perspectives for a holistic study experience. Students in these programs expect to be trained holistically as many plan to work on pressing societal, technical, or environmental problems (Armstrong, 1980) after graduation. Consequently, interdisciplinary study programs that want to provide an integrated study experience need to proactively address synthesis of knowledge of the involved disciplines. Our studies shed light on students' perception of their study programs regarding interdisciplinarity. As integration and synthesis of knowledge are key indicators for differentiating between interdisciplinarity and multidisciplinarity (Repko et al., 2014), we conclude that many students perceive their programs as less interdisciplinary and integrative than the program description might have promised (Spelt et al., 2009). Oftentimes, a mere juxtaposition of disciplines is provided, and students are left to themselves to find disciplinary interconnections and synthesis. Here, our results show that success in interdisciplinary study programs is closely connected with this perception.

The framework for interdisciplinarity in higher education by Spelt et al. (2009) postulates an interactive system of student characteristics and learning environment as important predictors of study outcomes in interdisciplinary study programs. Our research seizes this conceptualization of factors contributing to interdisciplinary outcomes. It establishes links between indicators of synthesis of knowledge as characteristics of the learning environment, social and academic integration, expectations, and perceived synthesis of knowledge as students' characteristics and general study outcomes.

Strengths, Limitations, and Future Research Prospects

With any research, strengths and limitations must be weighed. Our research provides new insights into study success in interdisciplinary study programs by examining how the organization and design of interdisciplinary study programs shape the study experience. Study 1 provided a general overview of this issue based on a variety of different interdisciplinary study programs. Study 2 linked student perceptions to features of specific interdisciplinary study programs and enabled a closer look at the mechanisms of how synthesis of knowledge in the study program affects study outcomes. Thereby, our set of studies made use of a mixed-methods approach combining data from different sources.

The framework by Spelt et al. (2009) for interdisciplinarity in higher education sees interdisciplinary thinking as the main study outcome of interdisciplinary study programs. In our studies, we used more general study outcomes such as study satisfaction and dropout intentions. Future research should extend this scope and include more specific measures of interdisciplinary thinking such as performance measures.

Furthermore, neither the framework by Spelt et al. (2009) nor our study take into account the perspective of the lecturers. In interdisciplinary study programs, lecturers play an important role in imparting knowledge of disciplines but also in integrating perspectives. To do so, their experiences and identities are particularly relevant. Challenges might present differently if lecturers have been interdisciplinarily educated themselves versus identifying with one discipline. Here, more research is necessary to understand how lecturers can facilitate interdisciplinary knowledge integration.

A noteworthy limitation of our study lies in the cross-sectional design of this research. Future studies should take longitudinal data into account to study the interplay of students' expectations, the design of the study program, students' perceptions of interdisciplinary synthesis, and study outcomes over time.

Practical Implications

Our studies underline the importance of social and academic integration for study success. Although integration is important in any study program (Tinto, 1993), our research implies that this is particularly the case for interdisciplinary study programs. Thus, universities and study program managers should facilitate interactions with faculty members but also ensure that students get to meet within their study programs to build relationships with their peers.

In addition, the timing of integrative teaching formats within the study program should be considered. When students' expectations of interdisciplinary integration are disappointed, dropout intentions rise and might lead to actual dropouts. Capstone seminars that are offered at the end of the study program would be too late to create perceived synthesis of knowledge for these students. Consequently, integrative formats should be included throughout the study program. Please note that freshmen in particular might be easily over-challenged by interdisciplinary formats as was reported by one of the interview partners in Study 2 (see p. 121).

Integrative teaching formats by themselves could only partly explain students' perceived synthesis of knowledge. We argue that lecturers can seize the opportunity to include integrative perspectives in any course within an interdisciplinary study program. Examples, case studies, and discussions can establish links and connections to other disciplinary perspectives regardless of the teaching format and didactic concept.

Finally, we conclude that students' perceptions of interdisciplinarity in their study programs should be included in evaluations of those programs. Perceived synthesis of knowledge and the fulfillment of expectations regarding interdisciplinarity proved important for relevant study outcomes in any interdisciplinary study program and hence should be introduced as an additional measure for evaluation.

References

Armstrong, F. H. (1980). Faculty development through interdisicplinarity. *Journal of General Education, 32,* 52-63.

Augsburg, T. (2003). Becoming interdisciplinary: The student portfolio in the bachelor of interdisciplinary studies program at Arizona State University. *Issues in Integrative Studies, 21,* 98-125.

Becher, T., & Trowler, P. R. (2001). *Academic tribes and territories. Intellectual enquiry and the culture of disciplines*. Ballmoor, UK: SRHE.

Brint, S. G., Turk-Bicakci, L., Proctor, K., & Murphy, S. P. (2009). Expanding the social frame of knowledge: Interdisciplinary, degree-granting fields in American colleges and universities, 1975-2000. *The Review of Higher Education, 32,* 155-183.

Dahm, G., Lauterbach, O., & Hahn, S. (2016). Measuring students' social and academic integration-Assessment of the operationalization in the National Education Panel Study. In H.-P. Blossfeld, J. von Maurice, M. Bayer, & J. Skopek (Eds.), *Methodological issues of longitudinal surveys. The example of the National Educational Panel Study* (pp. 313-329). Wiesbaden: Springer VS.

Devlieger, I., & Rosseel, Y. (2017). Factor score path analysis: an alternative for SEM? *Methodology, 13,* 31-38. doi:10.1027/1614-2241/a000130

Gaff, J. G. (1980). Avoiding the potholes: Strategies for reforming general education. *Educational Record, 61,* 50-59.

Godemann, J. (2006). Promotion of interdisciplinary competence as a challenge for higher education. *Journal of Social Science Education, 5*(sill), 51 - 61. doi:10.2390/jsse-v5-i4-1029

Grässmann, R., Schultheiss, O. C., & Brunstein, J. C. (1998). Exploring the determinants of students' academic commitment. In P. Nenniger, R. S. Jäger, A. Frey, & S. Wosnitza (Eds.), *Advances in motivation* (pp. 103-109). Landau: Verlag Empirische Pädagogik.

Klein, J. T., & Newell, W. H. (1996). Advancing interdisciplinary studies. In J. Gaff & J. Ratcliff (Eds.), *Handbook of the undergraduate curriculum* (pp. 3-22). San Francisco: Jossey-Bass.

Knight, D. B., Lattuca, L. R., Kimball, E. W., & Reason, R. D. (2013). Understanding interdisicplinarity: curricular and organizational features of undergraduate interdisciplinary programs. *Innovative Higher Education, 38*, 143-158. doi:10.1007/s10755-012-9232-1

Lindvig, K., & Ulriksen, L. (in press). Different, difficult and local: a review of interdisciplinary teaching activities. *The Review of Higher Education*.

Miller, M., & Boix-Mansilla, V. (2004). *Thinking across perspectives and disciplines* (Vol. 27). Cambridge, MA: Harvard Graduate School of Education.

Minnis, M., & John-Steiner, V. (2005). The challenge of integration in interdisciplinary education. *New Directions for Teaching and Learning, 102,* 45-61. doi:10.1002/tl.196

Newell, W. H. (1992). Academic disciplines and undergraduate interdisciplinary education: lessons from the school of interdisciplinary studies at Miami University, Ohio. *European Journal of Education, 27*, 211-221.

Pascarella, E. T., & Terenzini, P. T. (1980). Predicting freshman persistence and voluntary dropout decisions from a theoretical model. *The Journal of Higher Education, 51*, 60-75.

Repko, A. F., Szostak, R., & Buchberger, M. P. (2014). *Introduction to interdisciplinary studies*. Los Angeles, CA: Sage.

Rosseel, Y. (2012). lavaan: an R package for structural equation modeling. *Journal of Statistical Software, 48*, 1-36. doi:10.18637/jss.v048.i02

Schiefele, U., & Jacob-Ebbinghaus, L. (2006). Lernermerkmale und Lehrqualität als Bedingungen der Studienzufriedenheit [Learner characteristics and teacher quality as

prerequisits for study satisfaction]. *Zeitschrift für Pädagogische Psychologie, 20*, 199-212. doi:10.1024/1010-0652.20.3.199

Sill, D. J. (1996). Integrative thinking, synthesis, and creativity in interdisciplinary studies. *Journal of General Education, 50,* 129-151. doi: 0.1353/jge.2001.0032

Smith, J. S., & Wertlieb, E. C. (2005). Do first-year colllege students' expectations align with their first-year experiences? *Journal of Student Affairs Research and Practice, 42*, 153-174. doi:10.2202/1949-6605.1470

Spelt, E. J. H., Biemans, H. J. A., Tobi, H., Luning, P. A., & Mulder, M. (2009). Teaching and learning in interdisciplinary higher education: a systematic review. *Educational Psychology Review, 21,* 365-378. doi:10.1007/s10648-009-9113-z

Spelt, E. J. H., Luning, P. A., van Boekel, M. A. J. S., & Mulder, M. (2015). Constructively aligned teaching and learning in higher education in engineering: what do students perceive as contributing to the learning of interdisciplinary thinking? *European Journal of Engineering Education, 40,* 459-475. doi:10.1080/03043797.2014.987647

Sung, N. S., Gordon, J. I., Rose, G. D., Getzoff, E. D., Kron, S. J., Mumford, D., . . . Kopell, N. J. (2003). Educating future scientists. *Science, 301*, 1485. doi:t10.1126/science.10866133

Thiel, F., Blüthmann, I., & Richter, M. (2010). *Ergebnisse der Befragung der Studierenden in den Bachelorstudiengängen [Results of the survey of students in bachelor's programs]*. Retrieved from https://www.fu-berlin.de/sites/qm/verfahren/qualitaetssicherungsverfahren/zentrale-befragungen/bachelorbefragung/bachelorbefragung-2010.pdf

Tinto, V. (1993). *Leaving college: rethinking the causes and cures of student attrition*. Chicago, IL: University of Chicago Press.

Trautwein, U., Jonkmann, K., Gresch, C., Lüdtke, O., Neumann, M., Klusmann, U., & Baumert, J. (2007). *Transformation des Sekundarschulsystems und akademische*

Karrieren (TOSCA) Dokumentation der eingesetzten Items und Skalen. Welle 3. [Transformation of the secondary schooling system and academic careers (TOSCA). Documentation of items and scales used. Wave 3]. Max Planck Institute for Human Development. Berlin, Germany.

General Discussion

The aim of this thesis was to study how individuals can master interdisciplinarity in work and studies. In three manuscripts I explored different aspects of interdisciplinarity from a psychological perspective. Here, individual behaviors and experiences were central to my work.

In Manuscript I, I examined how individual competencies can support effective interdisciplinary collaborations and developed a model of interdisciplinary competencies comprising the four competency dimensions *initiative for exchange*, *target group-specific communication*, *knowledge integration*, and *reflection*. Knowledge integration is the most cognitively demanding competency in the model and directly linked to the integrative claim of interdisciplinarity. Hence, I studied knowledge integration in more detail in Manuscript II. Finally, in Manuscript III knowledge integration on the organizational level was studied in relation to individual-level outcomes in the study context.

Integration of Main Findings

I set out to better understand psychological mechanisms for mastering interdisciplinarity. My research was set in different contexts, and examined different conceptual levels. The main findings are summarized in Figure 1.

Different conceptual levels: individual, interpersonal and organizational perspectives.

To recap the main findings from my research, I will consider results on the (1) individual, (2) interpersonal, and (3) organizational level. Please note, however, that effects may cross different conceptual levels. In addition, some concepts can be situated on different levels and are here considered in the primary context I studied within my doctoral dissertation.

Individuals (1) can manage interdisciplinarity at work by means of the specific, interdisciplinary competencies *initiative for exchange, knowledge integration, target group-*

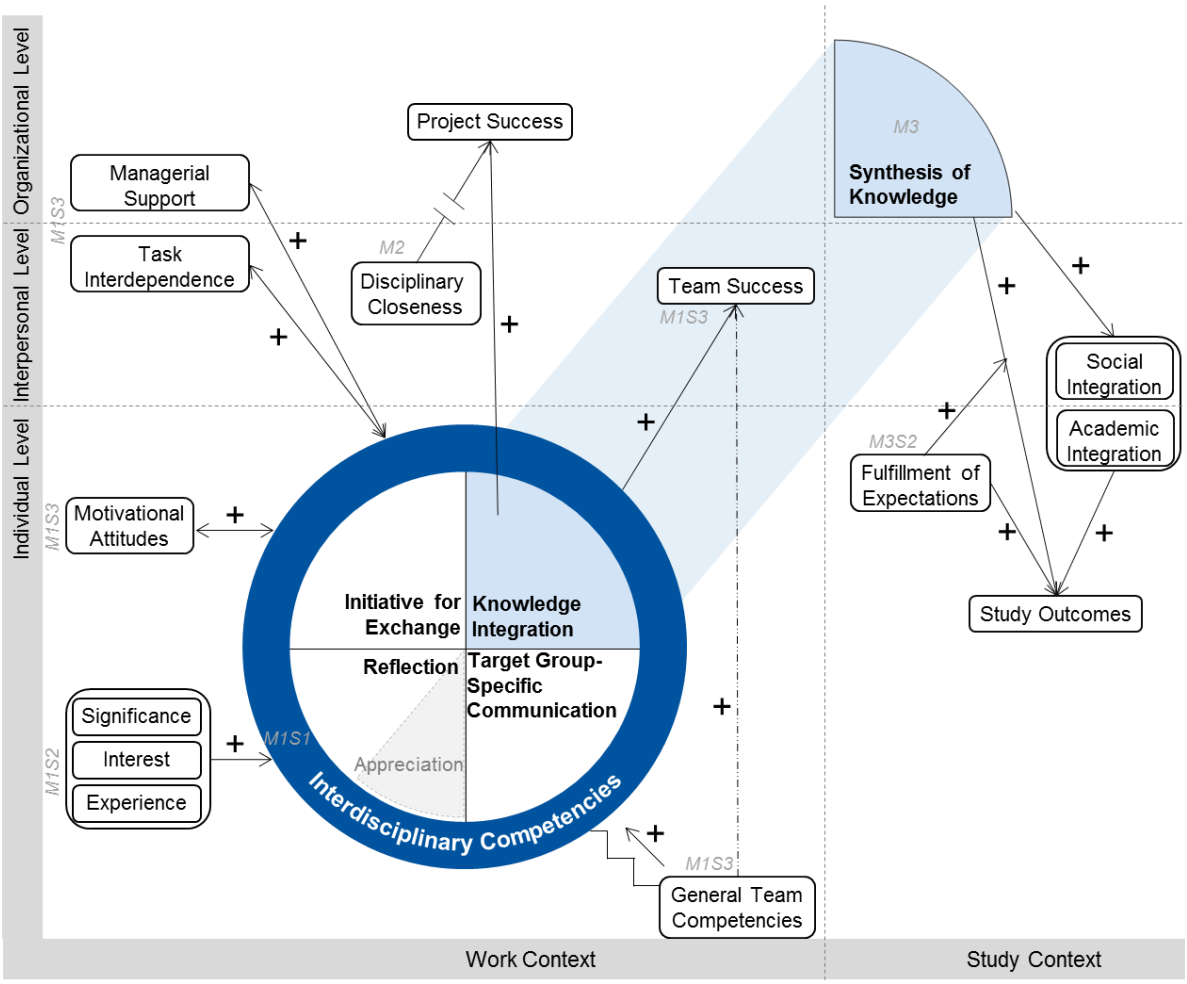

Figure 1. Summary of main results. The rows differentiate the individual, interpersonal, and organizational level. Research in the work context is shown on the left and educational settings are on the right. The respective manuscript and studies are set in italics. + symbolizes positive relations between constructs, the disconnected arrow refers to no significant association.

specific communication, and *reflection of their own disciplinary perspective*. These competencies proved to explain interdisciplinary team outcomes above and beyond general teamwork competencies. People were more likely to have interdisciplinary competencies if they perceived the interdisciplinary aspect of their work as interesting or significant for their job. In addition, I found that interdisciplinary competencies were related to a general liking of teamwork and the belief that one works well in team settings. Prior experience in interdisciplinary work was also associated with higher interdisciplinary competencies.

Therefore, I conclude that there are individual prerequisites both motivational and competency-related which are relevant in interdisciplinary work settings.

Looking at interdisciplinary study programs, we found that again, people's experiences mattered. Here, students' perception of their study programs as integrative was considered as a core predictor for individual study outcomes. In addition, my research showed that students' cognition about their own academic development (i.e., academic integration) was relevant to their individual study outcomes. Furthermore, we found that students whose expectations regarding the interdisciplinarity of their study programs were fulfilled were more satisfied, met their own academic achievement expectations better, and had fewer intentions to dropout from their programs. The results indicate that students might master interdisciplinary study programs by working on disciplinary integration—even if that requires having to do so by themselves.

At the interpersonal or team-level (2), we found that task interdependence was related to interdisciplinary competencies. This means that individuals who work in teams with tightly connected or interwoven work tasks had higher interdisciplinary competencies. The closeness of the disciplines involved in the collaboration regarding concepts, theories, and methods, however, proved not to be significant in predicting success. Collaborations between closely connected disciplines can be as difficult as those in which larger disciplinary differences have to be bridged. Furthermore, the research conducted for this doctoral dissertation showed that teams benefit from members with interdisciplinary competencies. Members were more satisfied with the collaboration and experienced the work to be more effective, when they had a competent team member or thought themselves to be interdisciplinarily competent.

But interpersonal aspects are also relevant in interdisciplinary study programs. Here, interactions with peers and faculty members were associated with positive outcomes. This social embeddedness might be more difficult to achieve in less integrative programs, but proved to be particularly valuable.

Finally, organizations (3) play a role in forming interdisciplinarity. In the work context, this doctoral dissertation showed that managers' support for interdisciplinarity (e.g., indicated by providing an adequate amount of time for interdisciplinary coordination) was associated with higher interdisciplinary competencies—one could say it takes time, support, and effort to build those. Individuals who reported higher interdisciplinary competencies, especially knowledge integration competency, also reported more success in their interdisciplinary projects and endeavors.

With regard to interdisciplinary study programs, this doctoral dissertation predominantly examined organizational means and their perception by students. As interdisciplinary study programs pose the challenge of knowledge integration for students, universities can support them by creating programs that are well-thought-out in how synthesis of knowledge can be achieved. My research demonstrates that synthesis is not a simple function of offering specific teaching formats, but there seems to be more (or less) involved in designing study programs which students perceive as integrated. Nevertheless, perceived synthesis of knowledge in the study programs was associated with subjective and self-reported objective study success.

Knowledge integration: getting to the core of interdisciplinarity.

"Most intellectual training focuses on analytical skills. Whether in literary criticism or scientific investigation, the academic mind is best at taking things apart. The complementary arts of integration are far less well developed. […] As with any interdisciplinary pursuit, it is the bridging across disparate ways of knowing that is the constant challenge."

Richard J. Borden[11]

The first studies considered four different interdisciplinary competencies, and the results indicated that particularly knowledge integration was highly relevant due to high

[11] Borden (2014)

correlations with convergent concepts and its predictive validity for team outcomes. As knowledge integration is the defining part of interdisciplinarity (Repko, 2012), the focus in my following research lay on integrative competencies or organizational means for integration respectively. It is, however, also the most difficult and cognitively demanding aspect. Here we observe individual differences in the ability to create integration. A noteworthy finding in the dissertation was that the assessment of a peer's competency for knowledge integration seemed to be very different from the self-report. Individuals do not know what kind of information a colleague with a different disciplinary background has and could possibly integrate. Therefore, people struggle to answer to what degree a peer was able to combine different disciplinary ideas.

In my studies, knowledge integration competency was related to more positive outcomes for teams and organizations. Hence, one could say that interdisciplinary teams in which knowledge integration happened tapped the full potential of interdisciplinarity. While Repko (2012) describes steps of the integrative process, it remains unclear how teams and team members in particular can initiate knowledge integration. Furthermore, my research indicates that there was only a weak association between knowledge integration and previous experiences in interdisciplinary work (see Manuscript I, study 2). This result challenges the idea by van Knippenberg et al. (2004) that integrative abilities are "picked up" by team members and can then be transferred to future teams.

Strengths, Limitations, and Implications for Future Research

With any research, strengths and limitations have to be weighted. The following sections will focus on the contributions and strengths of the doctoral dissertation as a whole, point out limitations, and discuss implications for future research in the field of interdisciplinarity.

Though much research has already been conducted on interdisciplinarity, empirical, psychological studies are still amiss in this field. This dissertation can be seen as a first step to fill this gap.

Within this dissertation, I have developed a model of interdisciplinary competencies that can provide the basis for research endeavors focusing on the individual in interdisciplinary work settings. The scales which were developed to measure interdisciplinary competencies in a self- and a peer-report version enable the scientific community to engage in research that takes individual differences in the skills and abilities for effective collaboration into account. Furthermore, a short scale for perceived synthesis of knowledge was developed to include students' perceptions of their interdisciplinary study programs when researching interdisciplinarity in an educational setting. These instruments make different aspects of interdisciplinarity as a phenomenon researchable for the scientific community, particularly for the psychological scientific community.

To answer the research questions presented in this doctoral dissertation, I employed a variety of methods. The combination of qualitative and quantitative research methods is particularly valuable as both approaches complement each other (Eisenhardt & Graebner, 2007). Furthermore, in quantitative research an adequate statistical representation of the research questions and the data on hand is necessary to create substantial results. Consequently, I used advanced statistical procedures (e.g., ESEM, factor score moderation, multilevel path analyses) to get a better grasp of the information presented in the data.

I used a disciplinary approach to study interdisciplinarity. While my research topic crosses disciplinary borders, I did not. I am a psychologist by training and used the methods, theories and concepts of my discipline to study interdisciplinarity. This psychological perspective comes with a focus on individual behaviors and experiences, although in the broader context of teams and organizations. From my point of view, I address relevant psychological research questions in the field of interdisciplinarity. Nevertheless, my

perspective is limited and in the context of a doctoral dissertation on disciplinary border crossing, this has to be pointed out.

While I studied interdisciplinarity in the work context and in the study context separately, future research should bring these two fields together. Interdisciplinary study programs are supposed to prepare graduates for work across disciplinary borders; therefore, they should be competent in conducting interdisciplinary work and research (see Mittelstraß, 1987). This assumption should be tested. Because many students perceived their interdisciplinary study programs to be only little integrated it remains questionable whether knowledge integration is actually a competency that students learn in these programs. New insights into the development of interdisciplinary competencies in interdisciplinary study programs could in turn inform the design of future programs to make sure the holistic and innovative claim of the programs are realized.

In addition, I did point out in the introduction that academic disciplines are not random entities as they come with a social identity. We know that these disciplinary identities make interdisciplinary work hard (Epstein, 2005), but it is unclear whether this is the case for all disciplines in the same way. Disciplines differ not only regarding their communities, theories, methods, and epistemological approaches, but possibly also in the strength of the social identity they provide. In the same way that social groups differ in their cohesiveness, disciplines may be distinguished in how strongly members identify with them. Here, a clear understanding and reflection of the discipline both by individual members and the community as a whole, might play a central role. Future research should address disciplinary identities in interdisciplinary settings as their role could be two-edged. On the one hand, a strong disciplinary identity and a clear idea of one's own disciplinary competencies make disciplinary borders particularly visible. Interactions with people from other disciplines may challenge one's disciplinary identity (Lindvig & Ulriksen, in press). In addition, disciplinary cultures can generate negative attitudes towards others disciplines (Antons et al., 2017) which

make collaboration more difficult (Antons & Piller, 2015). On the other hand, a fuzzy idea of one's own discipline and its field of knowledge could contribute to amateurism and conceptual confusion, which is a common criticism of interdisciplinary research (Berger et al., 2014; Davis, 2007).

In my research, I had a broad understanding of interdisciplinarity (see Moran, 2010). I included participants who perceived their work to be interdisciplinary and asked them to describe the different disciplinary backgrounds. It became evident that interdisciplinarity is a term open for interpretation. Some participants had difficulties to describe their own discipline, because they studied different (interdisciplinary) study programs, and identified with a transdisciplinary role (Hagoel & Kalekin-Fishman, 2002). In other cases, participants said they worked interdisciplinarily, but, from my perspective the disciplinary backgrounds of the target person and their colleague sounded very similar. In my research, I tried to accommodate these different understandings of interdisciplinarity, for example by looking at disciplinary closeness. There were, however, no effects for disciplinary closeness. This makes the phenomenon not less complicated. In the same vein, examining curricula of interdisciplinary study programs revealed that there were more differences than similarities between interdisciplinary study programs. Programs differed profoundly in regards of their set-up, integrative attempts, and from my impression as an interviewer, in how well they were thought out. Again, this heterogeneity presents a difficulty in comparing programs and finding patterns across programs, but this variety lies in the nature of the subject of interdisciplinarity. I studied interdisciplinarity in its heterogeneity, including different contexts, work settings, and constellations. While this can make effects less defined, it also contributes to the generalizability of my findings. No matter the specific details of the interdisciplinary endeavor, to make use of the various disciplinary perspectives interdisciplinary competencies are required, particularly integrative ones.

Concluding Remarks

„Is interdisciplinarity valuable in itself?“

Bammer[12]

Many people don’t engage in interdisciplinary endeavors because they enjoy it so much (although many do), but rather because they see an opportunity in leaving their artificial “territory” (Becher & Trowler, 2001) behind to work on an interesting problem and hopefully develop something innovative. Nevertheless, this proves to be hard due to disciplinary identities, engrained approaches, and complicated collaborations. Yet it can be done. This doctoral dissertation demonstrates that there are starting points for individuals, teams, and organizations to make interdisciplinarity a success. Interdisciplinarity is not an end in itself, but a means to solve problems that transcend the realm of a single discipline.

[12] Bammer (2003,p. 54, cited from Lerch,2017, p. 51) . German original „ Ist Interdisziplinarität ein Wert an sich?“

References

Aboelela, S. W., Larson, E., Bakken, S., Carrasquillo, O., Formicola, A., Glied, S. A., . . . Gebbie, K. M. (2007). Defining interdisciplinary research: Conclusions from a critical review of the literature. *Health Services Research, 42*, 329 - 346. doi:10.1111/j.1475-6773.2006.00621.x

Antons, D., Declerck, M., Diener, K., Koch, I., & Piller, F. T. (2017). Assessing the not-invented-here syndrome: Development and validation of implicit and explicit measurements. *Journal of Organizational Behavior, 38*(8), 1227-1245. doi:10.1002/job.2199

Antons, D., & Piller, F. T. (2015). Opening the black box of "Not invented Here": Attitudes, decision biases, and behavioral consequences. *Academy of Management Perspectives, 29*(2), 193-217. doi:10.5465/amp.2013.0091

Armstrong, F. H. (1980). Faculty development through interdisciplinarity. *Journal of General Education, 32*, 52-63.

Asparouhov, T., & Muthén, B. (2009). Exploratory structural equation modeling. *Structural Equation Modeling, 16*, 397–438. doi:10.1080/10705510903008204

Augsburg, T. (2003). Becoming interdisciplinary: The student portfolio in the bachelor of interdisciplinary studies program at Arizona State University. *Issues in Integrative Studies, 21*, 98-125.

Bandura, A. (1994). Self-efficacy. In V. S. Ramachaudran (Ed.), *Encyclopedia of human behavior* (Vol. 4, pp. 71-81). New York: Academic Press.

Bandura, A., & Schunk, D. H. (1981). Cultivating competence, self-efficacy, and intrinsic interest through proximal self-motivation. *Journal of Personality and Social Psychology, 41*, 586–598. doi:10.1037/0022-3514.41.3.586

Baruch, Y., & Cohen, A. (2007). The dynamics between organisational commitment and professional identity formation at work. In A. Brown, S. Kirpal, & F. Rauner (Eds.),

Identities at work. Technical and vocational education and training: issues, concerns and prospects (pp. 241-260). Dordrecht, Netherlands: Springer. doi:10.1007/978-1-4020-4989-7

Becher, T., & Trowler, P. R. (2001). *Academic tribes and territories. Intellectual enquiry and the culture of disciplines*. Ballmoor, UK: SRHE.

Berger, W., Winiwarter, V., Dressel, G., & Heimerl, K. (2014). Methoden und Praktiken interdisziplinärer und transdisziplinärer Wissenschaft [Methods and practices of interdisciplinary and transdisciplinary research]. In G. Dressel, W. Berger, K. Heimerl, & V. Winiwarter (Eds.), *Interdisziplinär und transdisziplinär forschen [interdisciplinary and transdisciplinary research]* (pp. 17-28). Bielefeld: transcript Verlag.

Biglan, A. (1973). The characteristics of subject matter in different academic areas. *Journal of Applied Psychology, 57*, 195-203. doi:10.1037/h0034701

Borden, R. J. (2014). *Ecology and experience: reflection from a human ecological perspective*. Berkeley, CA: North Atlantic Books.

Boyatzis, R. E. (2008). Competencies in the 21st century. *Journal of Management Development, 27*(1), 5-12. doi:10.1108/02621710810840730

Brandstädter, S., & Sonntag, K. (2016). Interdisciplinary collaboration: How to foster the dialogue across disciplinary borders? In B. Deml, P. Stock, R. Bruder, & C. Schlick (Eds.), *Advances in ergonomic design of systems, products and processes* (pp. 395–410). Berlin: Springer. doi:10.1007/978-3-662-48661-0

Brew, A. (2008). Disciplinary and interdisciplinary affiliations of experienced researchers. *Higher Education, 56*, 423-438. doi:10.1007/s10734-007-9102-4

Brint, S. G., Turk-Bicakci, L., Proctor, K., & Murphy, S. P. (2009). Expanding the social frame of knowledge: Interdisciplinary, degree-granting fields in American colleges

and universities, 1975-2000. *The Review of Higher Education, 32*, 155-183. doi:10.1353/rhe.0.0042

Bromme, R. (2000). Beyond one's own perspective: The psychology of cognitive interdisciplinarity. In P. Weingart & N. Stehr (Eds.), *Practising interdisciplinarity* (pp. 115–133). Toronto: University of Toronto Press. doi:10.3138/9781442678729-008

Bromme, R., Jucks, R., & Rambow, R. (2003). Wissenskommunikation über Fächergrenzen: Ein Trainingsprogramm [Science communication across disciplinary borders: A training]. *Wirtschaftspsychologie [Business Psychology], 3*, 94 - 102.

Bronstein, L. R. (2003). A model for interdisciplinary collaboration. *Social Work, 48*, 297–306. doi: 10.1093/sw/48.3.297

Bruce, A., Lyall, C., Tait, J., & Williams, R. (2004). Interdisciplinary integration in Europe: The case of the fifth framework programme. *Futures, 36*(4), 457-470. doi:10.1016/j.futures.2003.10.003

Bunderson, J. S. (2003). Team member functional background and involvement in management teams: direct effects and the moderating role of power centralization. *Academy of Management Journal, 46*, 458-474. doi:10.2307/30040638

Campion, M. A., Medsker, G. J., & Higgs, A. C. (1993). Relations between work group characteristics and effectiveness: Implications for designing effective work groups. *Personnel Psychology, 46*, 823-850. doi:10.1111/j.1744-6570.1993.tb01571.x

Cheung, S. Y., Gong, Y., Wang, M., Zhou, L. B., & Shi, J. (2016). When and how does functional diversity influence team innovation? The mediating role of knowledge sharing and the moderation role of affect-based trust in a team. *Human Relations, 69*, 1–25. doi:10.1177/0018726715615684

Clark, H. H. (1996). *Using language*. Cambridge, UK: Cambridge University Press.

References

Cohen, W. M., & Levinthal, D. A. (1990). Absorptive capacity: A new perspective on learning and innovation. *Administrative Science Quarterly, 35*, 128-152. doi:10.2307/2393553

Crawford, L. (2005). Senior management perceptions of project management competence. *International Journal of Project Management, 23*, 7-16. doi:10.1016/j.ijproman.2004.06.005

Cronin, M. A., & Weingart, L. R. (2007). Representational gaps, information processing, and conflict in functionally diverse teams. *Academy of Management Review, 32*, 761-773 doi:10.2307/20159333

Cummings, J. N., & Kiesler, S. (2008). *Who collaborates successfully? Prior experience reduces collaboration barriers in distributed interdisciplinary research.* Paper presented at the Computer Supported Cooperative Work, San Diego, California.

Dahlin, K. B., Weingart, L. R., & Hinds, P. J. (2005). Team diversity and information use. *Academy of Management Journal, 48*, 1107-1123. doi:10.5465/AMJ.2005.19573112

Dahm, G., Lauterbach, O., & Hahn, S. (2016). Measuring students' social and academic integration - assessment of the operationalization in the National Education Panel Study. In H.-P. Blossfeld, J. von Maurice, M. Bayer, & J. Skopek (Eds.), *Methodological issues of longitudinal surveys. The example of the National Educational Panel Study* (pp. 313-329). Wiesbaden: Springer VS. doi:10.1007/978-3-658-11994-2_18

Davis, L. J. (2007). A grand unified theory of interdisciplinarity. *Chronicle of Higher Education, 53*, B9.

de Saint-Exupéry, A. (1943). *The little prince*. New York, NY: Reynal & Hitchcock.

de Wit, A. (1988). Measurement of project success. *International Journal of Project Management, 6*(3), 164-170. doi:10.1016/0263-7863(88)90043-9

References

Defila, R., & Di Giulio, A. (1998). Interdisziplinarität und Disziplinarität [Interdisciplinarity and disciplinarity]. In J. H. Olbertz (Ed.), *Zwischen den Fächern über den Dingen? Universalisierung versus Spezialisierung akademischer Bildung [Between subjects above things? Universalization versus specialization of academic education]* (pp. 111-138). Opladen: Leske+Budrich doi:10.1007/978-3-322-90935-0_6

Defila, R., Di Giulio, A., & Scheuermann, M. (2006). *Forschungsverbundmanagement. Handbuch für die Gestaltung inter- und transdisziplinärer Projekte [Research network management. Handbook for the design of interdisciplinary and transdisciplinary projects]*. Zürich: vdf Hochschulverlag.

DeStatis. (2015). Studierende an Hochschulen - Fächersystematik [University students - classification of study programs]. Retrieved from https://www.destatis.de/DE/Methoden/Klassifikationen/BildungKultur/StudentenPruefungsstatistik.pdf?__blob=publicationFile

Devlieger, I., & Rosseel, Y. (2017). Factor score path analysis: an alternative for SEM? *Methodology, 13*, 31-38. doi:10.1027/1614-2241/a000130

DFG. (2013). *Fachübergreifende Begutachtung: Strukturwirkung und Fördererfolg [Interdisciplinary Assessment: Structural Effect and Funding Success]*. Bonn: DFG.

Eby, L. T., & Dobbins, G. H. (1997). Collectivistic orientation in teams: an individual and group-level analysis. *Journal of Organizational Behavior, 18*, 275-295. doi:10.1002/(SICI)1099-1379(199705)18:3<275::AID-JOB796>3.0.CO;2-C

Eid, M., Lischetzke, T., & Nussbeck, F. W. (2006). Structural equation models for multitrait-multimethod data. In M. Eid & E. Diener (Eds.), *Handbook of multimethod measurement in psychology* (pp. 283-299). Washington, DC: American Psychological Association. doi:10.1037/11383-020

References

Eisenhardt, K. M., & Graebner, M. E. (2007). Theory building from cases: Opportunities and challenges. *Academy of Management Journal, 50*(1), 25–32. doi:10.5465/amj.2007.24160888

Epstein, S. L. (2005). Making interdisciplinary collaboration work. In S. J. Derry, C. D. Schunn, & M. A. Gernsbacher (Eds.), *Interdisciplinary collaboration. An emerging cognitive science* (pp. 245–263). New York: Lawrence Erlbaum Associates.

Ericsson, K. A., & Simon, H. A. (1993). *Protocol analysis: Verbal reports as data*. Cambridge: MIT Press.

FAME Consortium. (2007). Decomposing and recomposing occupational identities - a survey of theoretical concepts. In A. Brown, S. Kirpal, & F. Rauner (Eds.), *Identities at work. Technical and vocational education and training: issues, concerns and prospects* (pp. 13-44). Dordrecht, Netherlands: Springer. doi:10.1007/978-1-4020-4989-7

Finegold, D., & Matousek, R. (2007). US efforts to create a new professional identity for the bioscience industry. In A. Brown, S. Kirpal, & F. Rauner (Eds.), *Identities at work. Technical and vocational education and training: issues, concerns and prospects* (pp. 361-390). Dordrecht, Netherlands: Springer. doi:10.1007/978-1-4020-4989-7

Flanagan, J. C. (1954). The critical incident technique. *Psychological Bulletin, 51*, 327–359. doi:10.1037/h0061470

Frese, M. (1982). Occupational socialization and psychological development: an underemphasized research perspective in industrial psychology. *Journal of Occupational Psychology, 55*, 209-224. doi:10.1111/j.2044-8325.1982.tb00095.x

Gaff, J. G. (1980). Avoiding the potholes: Strategies for reforming general education. *Educational Record, 61*, 50-59.

Godemann, J. (2006). Promotion of interdisciplinary competence as a challenge for higher education. *Journal of Social Science Education, 5*(sill), 51 - 61. doi:10.2390/jsse-v5-i4-1029

References

Grässmann, R., Schultheiss, O. C., & Brunstein, J. C. (1998). Exploring the determinants of students' academic commitment. In P. Nenniger, R. S. Jäger, A. Frey, & S. Wosnitza (Eds.), *Advances in motivation* (pp. 103-109). Landau: Verlag Empirische Pädagogik.

Hagoel, L., & Kalekin-Fishman, D. (2002). Crossing borders: toward a trans-disciplinary scientific identity. *Studies in Higher Education, 27*, 297-308. doi:10.1080/03075070220000680

Halfhill, T. R., & Nielsen, T. M. (2007). Quantifying the "softer side" of management education: an example using teamwork competencies. *Journal of Management Education, 31*(1), 64-80. doi:10.1177/1052562906287777

Heid, H. (1989). Interdisziplinarität [Interdisciplinarity]. In D. Lenzen (Ed.), *Pädagogische Grundbegriffe 1: Aggression - Interdisziplinarität [Fundamental terms of pedagogics 1: aggression - interdisciplinarity]* (pp. 781-798). Reinbek, Germany: Rowohlt.

Heidemeier, H., & Moser, K. (2009). Self-other agreement in job performance ratings: A meta-analytical test of a process model. *Journal of Applied Psychology, 94*, 353-370. doi:10.1037/0021-9010.94.2.353

Hertel, G., Konradt, U., & Orlikowski, B. (2004). Managing distance by interdependence: Goal setting, task interdependence, and team-based rewards in virtual teams. *European Journal of Work and Organizational Psychology, 13*(1), 1-28. doi:10.1080/13594320344000228

Hoever, I. J., van Knippenberg, D., van Ginkel, W. P., & Barkema, H. G. (2012). Fostering team creativity: Perspective taking as key to unlocking diversity's potential. *Journal of Applied Psychology, 97*, 982-996. doi:10.1037/a0029159

Homan, A. C., van Knippenberg, D., van Kleef, G. A., & De Dreu, C. K. W. (2007). Bridging faultlines by valuing diversity: diversity beliefs, information elaboration, and performance in diverse work groups. *Journal of Applied Psychology, 92*, 1189-1199. doi:10.1037/0021-9010.92.5.1189

References

Hübenthal, U. (1994). Interdisciplinary thought. *Issues in Integrative Studies, 12*, 55-75.

Huutoniemi, K., Klein, J. T., Bruun, H., & Hukkinen, J. (2010). Analyzing interdisciplinarity: Typology and indicators. *Research Policy, 39,* 79 - 88. doi:10.1016/j.respol.2009.09.011

Jacobs, J. A., & Frickel, S. (2009). Interdisciplinarity: A critical assessment. *Annual Review of Sociology, 35*, 43-65. doi:10.1146/annurev-soc-070308-115954

Jooß, C., Thiele, T., Vossen, R., Richert, A., & Jeschke, S. (2015). Integrative knowledge management in interdisciplinary research clusters. *International Journal of Advanced Corporate Learning*, *8*(3), 17–22. doi:10.3991/ijac.v8i3.4854

Kaufmann, F.-X. (1987). Interdisziplinäre Wissenschaftspraxis: Erfahrungen und Kriterien [Interdisciplinary Science Practice: Experience and Criteria]. In J. Kocka (Ed.), *Interdisziplinarität. Praxis - Herausforderung - Ideologie [Interdisciplinarity. Practice - challenge - ideology]* (pp. 63-81). Frankfurt am Main: Suhrkamp.

Klein, J. T. (2010). A taxonomy of interdisciplinarity. In R. Frodeman (Ed.), *The oxford handbook of interdisciplinarity* (pp. 15-30). Oxford: Oxford University Press.

Klein, J. T., & Newell, W. H. (1996). Advancing interdisciplinary studies. In J. Gaff & J. Ratcliff (Eds.), *Handbook of the undergraduate curriculum* (pp. 3-22). San Francisco: Jossey-Bass.

Knight, D. B., Lattuca, L. R., Kimball, E. W., & Reason, R. D. (2013). Understanding interdisicplinarity: curricular and organizational features of undergraduate interdisciplinary programs. *Innovative Higher Education, 38*, 143-158. doi:10.1007/s10755-012-9232-1

Koch, A., Strobel, A., Kici, G., & Westhoff, K. (2009). Quality of the critical incident technique in practice: Interrater reliability and users' acceptance under real conditions. *Psychological Science Quarterly, 51*, 3–15.

References

Krapp, A. (2002). Structural and dynamic aspects of interest development: theoretical considerations from an ontogenetic perspective. *Learning and Instruction, 12*, 383–409. doi:10.1016/S0959-4752(01)00011-1

Lattuca, L. R., Knight, D. B., & Bergom, I. M. (2012). *Developing a measure of interdisciplinary competence for engineers*. Paper presented at the Conference of the American Society for Engineering Education (ASEE), San Antonio, TX.

Lattuca, L. R., Voight, L. J., & Fath, K. Q. (2004). Does interdisciplinarity promote learning? Theoretical support and researchable questions. *The Review of Higher Education, 28*, 23-48.

Lerch, S. (2017). *Interdisziplinäre Kompetenzen. Eine Einführung [Interdisciplinary competencies. An introduction]*. Münster: Waxmann.

Ley, T., Lindstaedt, S. N., & Albert, D. (2005). *Supporting competency development in informal workplace learning*. Paper presented at the Conference for Professional Knowledge Management, Kaiserslautern, Germany.

Lindberg, D. C. (1992). *The beginnings of western science: the European scientific tradition in philosophical, religious, and institutional context, 600 B.C. to A.D. 1450*. Chicago, Illinois: The University of Chicago Press.

Lindell, M. K., & Whitney, D. J. (2001). Accounting for common method variance in cross-sectional research designs. *Journal of Applied Psychology, 86*, 114-121. doi:10.1037//0021-9010.86.1.114

Lindvig, K., & Ulriksen, L. (in press). Different, difficult and local: a review of interdisciplinary teaching activities. *The Review of Higher Education*.

Luan, K., Ling, C.-D., & Xie, X.-Y. (2016). The nonlinear effects of educational diversity on team creativity. *Asia Pacific Journal of Human Resources, 54*, 465-480. doi:10.1111/1744-7941.12078

References

Maclean, R., & Wilson, D. N. (2007). Introduction by the series editors. In A. Brown, S. Kirpal, & F. Rauner (Eds.), *Identities at work. Technical and vocational education and training: issues, concerns and prospects* (pp. vii-x). Dordrecht, Netherlands: Springer. doi:10.1007/978-1-4020-4989-7

Marsh, H. W., Muthén, B., Asparouhov, T., Lüdtke, O., Robitzsch, A., Morin, A. J. S., & Trautwein, U. (2009). Exploratory structural equation modeling, integrating CFA and EFA: Application to students' evaluations of university teaching. *Structural Equation Modeling, 16*, 439–476. doi:10.1080/10705510903008220

Maynard, M. T., & Gilson, L. L. (2014). The role of shared mental model development in understanding virtual team effectiveness. *Group & Organization Management, 39*, 3–32. doi:10.1177/1059601113475361

Maynard, M. T., Mathieu, J. E., Rapp, T., & Gilson, L. L. (2012). Something(s) old and something(s) new: Modeling drivers of global virtual team effectiveness. *Journal of Organizational Behavior, 33*, 342-365. doi:10.1002/job.1772

Millar, M. M. (2013). Interdisciplinary research and the early career: The effect of interdisciplinary dissertation research on career placement and publication productivity of doctoral graduates in the sciences. *Research Policy, 42*, 1152-1164. doi:10.1016/j.respol.2013.02.004

Miller, M., & Boix-Mansilla, V. (2004). *Thinking across perspectives and disciplines* (Vol. 27). Cambridge, MA: Harvard Graduate School of Education.

Minnis, M., & John-Steiner, V. (2005). The challenge of integration in interdisciplinary education. *New Directions for Teaching and Learning, 102*, 45-61. doi:10.1002/tl.196

Mittelstraß, J. (1987). Die Stunde der Interdisziplinarität? [The hour of interdisciplinarity?]. In J. Kocka (Ed.), *Interdisziplinarität. Praxis - Herausforderung - Ideologie [Interdisciplinarity. Practice - challenge - ideology]* (pp. 152-158). Frankfurt am Main, Germany: Suhrkamp.

References

Moran, J. (2010). *Interdisciplinarity*. London, UK: Routledge.

Morin, A. J. S., Marsh, H. W., & Nagengast, B. (2013). Exploratory structural equation modeling. In G. R. Hancock & R. O. Mueller (Eds.), *Structural equation modeling: A second course* (pp. 395–437). Charlotte, NC: Information Age Publishing, Inc.

Muthén, L. K., & Muthén, B. O. (1998-2017). *Mplus user's guide*. Los Angeles, CA: Muthén & Muthén.

National Academy of Sciences, National Academy of Engineering, & Institute of Medicine of the National Academies. (2005). *Facilitating interdisciplinary research*. Washington, DC: The National Academies Press.

National Center for Education Statistics. (2010). Introduction to the classification of instructional programs: 2010 Edition (CIP-2010). Retrieved from https://nces.ed.gov/ipeds/cipcode/contact.aspx?y=55

Neumeier, R. (2007). *Interdisziplinäres Forschen [Interdisciplinary research]*. Frankfurt am Main: Peter Lang.

Newell, W. H. (1992). Academic disciplines and undergraduate interdisciplinary education: lessons from the school of interdisciplinary studies at Miami University, Ohio. *European Journal of Education, 27*, 211-221. doi:10.2307/1503450

Newell, W. H. (2001). A theory of interdisciplinary studies. *Issues in Integrative Studies, 19*, 1–25.

Nightingale, P., & Scott, A. (2007). Peer review and the relevance gap: ten suggestions for policy-makers. *Science and Public Policy, 34*, 543-553. doi:10.3152/030234207X254396

Palmer, C. L. (2001). *Work on the boundaries of science: information and the interdisciplinary research process*. Dordrecht, Netherlands: Springer.

References

Pascarella, E. T., & Terenzini, P. T. (1980). Predicting freshman persistence and voluntary dropout decisions from a theoretical model. *The Journal of Higher Education, 51*, 60-75. doi:10.2307/1981125

Pennington, D. (2015). A conceptual model for knowledge integration in interdisciplinary teams: orchestrating individual learning and group processes. *Journal of Environmental Studies and Sciences, 6*, 300-312. doi:10.1007/s13412-015-0354-5

Popper, K. R. (1962). *Conjectures and refutations: the growth of scientific knowledge*. New York, NY: Routledge.

Rafols, I. (2014). Knowledge integration and diffusion: Measures and mapping of diversity and coherence. In Y. Ding, R. Rousseau, & D. Wolfram (Eds.), *Measuring scholarly impact: Methods and practice* (pp. 169-190). Cham, Switzerland: Springer International Publishing. doi:10.1007/978-3-319-10377-8_8

Reich, S. M., & Reich, J. A. (2006). Cultural competence in interdisciplinary collaborations: A method for respecting diversity in research partnerships. *American Journal for Community Psychology, 38*, 51–62. doi: 10.1007/s10464-006-9064-1

Repko, A. F. (2012). *Interdisciplinary research: process and theory*. Los Angeles: Sage.

Repko, A. F., Szostak, R., & Buchberger, M. P. (2014). *Introduction to interdisciplinary studies*. Los Angeles, CA: Sage.

Rhoten, D., & Parker, A. (2004). Risks and rewards of an interdisciplinary research path. *Science, 306*, 2046. doi: 10.1126/science.1103628

Rogers, Y., Scaife, M., & Rizzo, A. (2005). Interdisciplinarity: An emergent or engineered process? In S. J. Derry, C. D. Schunn, & M. A. Gernsbacher (Eds.), *Interdisciplinary Collaboration* (pp. 265–286). Mahwah, NJ: Lawrence Erlbaum.

Rosseel, Y. (2012). lavaan: an R package for structural equation modeling. *Journal of Statistical Software, 48*, 1-36. doi:10.18637/jss.v048.i02

Sandberg, J. (2000). Understanding human competence at work: An interpretative approach. *Academy of Management Journal, 43*(1), 9-25. doi:10.2307/1556383

Schiefele, U., & Jacob-Ebbinghaus, L. (2006). Lernermerkmale und Lehrqualität als Bedingungen der Studienzufriedenheit [Learner characteristics and teacher quality as prerequisites for study satisfaction]. *Zeitschrift für Pädagogische Psychologie [Journal of Educational Psychology], 20*, 199-212. doi:10.1024/1010-0652.20.3.199

Sill, D. J. (1996). Integrative thinking, synthesis, and creativity in interdisciplinary studies. *Journal of General Education, 50*, 129-151. doi: 0.1353/jge.2001.0032

Skorikov, V., & Vondracek, F. W. (2011). Occupational identity. In S. Schwartz, K. Luyckx, & V. L. Vignoles (Eds.), *Handbook of identity theory and research* (pp. 693-714). New York, NY: Springer. doi:10.1007/978-1-4419-7988-9_29

Smith, J. S., & Wertlieb, E. C. (2005). Do first-year college students' expectations align with their first-year experiences? *Journal of Student Affairs Research and Practice, 42*, 153-174. doi:10.2202/1949-6605.1470

Spelt, E. J. H., Biemans, H. J. A., Tobi, H., Luning, P. A., & Mulder, M. (2009). Teaching and learning in interdisciplinary higher education: a systematic review. *Educational Psychology Review, 21*, 365-378. doi:10.1007/s10648-009-9113-z

Spelt, E. J. H., Luning, P. A., van Boekel, M. A. J. S., & Mulder, M. (2015). Constructively aligned teaching and learning in higher education in engineering: what do students perceive as contributing to the learning of interdisciplinary thinking? *European Journal of Engineering Education, 40*, 459-475. doi:10.1080/03043797.2014.987647

Steinheider, B. (2012). *Knowledge integration in research-practitioner collaborations*. Paper presented at the Science of Team Science Conference, Chicago, Il.

Steinheider, B., Bayerl, P. S., Menold, N., & Bromme, R. (2009). Entwicklung und Validierung einer Skala zur Erfassung von Wissensintegrationsproblemen in interdisziplinären Projektteams (WIP) [Development and validation of a scale for

assessing knowledge integration problems in interdisciplinary teams]. *Zeitschrift für Arbeits- und Organisationspsychologie [Journal for work and organizational psychology], 53*, 121–130. doi:10.1026/0932-4089.53.3.121

Stevens, M. J., & Campion, M. A. (1994). The knowledge, skill, and ability requirements for teamwork: Implications for human resource management. *Journal of Management, 20*, 503–530. doi:10.1016/0149-2063(94)90025-6

Sung, N. S., Gordon, J. I., Rose, G. D., Getzoff, E. D., Kron, S. J., Mumford, D., . . . Kopell, N. J. (2003). Educating future scientists. *Science, 301*, 1485. doi:t10.1126/science.10866133

Szostak, R. (2002). How to do interdisciplinarity: Integrating the debate. *Issues in Integrative Studies, 20*, 103–122.

Thiel, F., Blüthmann, I., & Richter, M. (2010). *Ergebnisse der Befragung der Studierenden in den Bachelorstudiengängen [Results of the survey of students in bachelor's programs]*. Retrieved from https://www.fu-berlin.de/sites/qm/verfahren/qualitaetssicherungsverfahren/zentrale-befragungen/bachelorbefragung/bachelorbefragung-2010.pdf

Tinto, V. (1993). *Leaving college: rethinking the causes and cures of student attrition*. Chicago, IL: University of Chicago Press.

Trautwein, U., Jonkmann, K., Gresch, C., Lüdtke, O., Neumann, M., Klusmann, U., & Baumert, J. (2007). *Transformation des Sekundarschulsystems und akademische Karrieren (TOSCA). Dokumentation der eingesetzten Items und Skalen. Welle 3. [Transformation of the secondary schooling system and academic careers (TOSCA). Documentation of items and scales used. Wave 3]*. Max Planck Institute for Human Development. Berlin, Germany.

References

U.S. census bureau, & Ryan, C. (2012). Field of degree and earnings by selected employment characteristics: 2011. Retrieved from https://www.census.gov/prod/2012pubs/acsbr11-10.pdf

United Nations. (2019). Global issues overview. Retrieved from https://www.un.org/en/sections/issues-depth/global-issues-overview/

Valls, V., González-Romá, V., & Tomás, I. (2016). Linking educational diversity and team performance: Team communication quality and innovation team climate matter. *Journal of Occupational and Organizational Psychology, 89*, 751-771. doi:10.1111/joop.12152

van Ginkel, W. P., & van Knippenberg, D. (2008). Group information elaboration and group decision making: The role of shared task representations. *Organizational Behavior and Human Decision Processes, 105*, 82–97. doi:10.1016/j.obhdp.2007.08.005

van Knippenberg, D., De Dreu, C. K. W., & Homan, A. C. (2004). Work group diversity and group performance: An integrative model and research agenda. *Journal of Applied Psychology, 89*, 1008–1022. doi:10.1037/0021-9010.89.6.1008

Webber, S. S., & Donahue, L. M. (2001). Impact of highly and less job-related diversity on work group cohesion and performance: A meta-analysis. *Journal of Management, 27*, 141-162. doi:10.1016/S0149-2063(00)00093-3

Williams, K. Y., & O'Reilly, C. A. (1998). Demography and diversity in organizations: A review of 40 years of research. *Research in Organizational Behavior, 20*, 77-140.

Appendix A: Supplementary Material to Manuscript I

Interview Protocol for Datasource 1

Welcome and warm up

- Welcoming
- Introduction of the interviewer
    - Reference to prior contact
- Thanking interviewee for participation
  Thank you for taking your time for a conversation with me.
- Information about goals and contents of the interview:
  This study is – as I have implied – about the development of a measure of interdisciplinary competencies. In a first step I want to capture all behavioral aspects that might be relevant for interdisciplinary practice.
  To do so, I interview people with a lot of experience in interdisciplinary work.
  Today, I want to ask for situations, in which differences between more and less interdisciplinary competent individuals emerge. This information will later be used to identify demands and competencies of interdisciplinary work.
- Information about the protocol
  During our interview I will stick to a protocol. This allows me to avoid forgetting certain points and provide comparable results across multiple interviews.
- Information about the time span
  As I mentioned in our prior contact, the interview will take roughly 30 to 40 minutes.
- Information about privacy policy
  All contents of the interview are subject to privacy policy and will be treated anonymously and confidential.
- Permission for recording the interview
  To be able to fully focus on the interview and to not lose any information due to missing notes, I would like to record the interview. Do you agree with a recording?
  Thank you. I will now turn on the recorder.
- Experience with interdisciplinary collaboration
  First of all, I would like to learn more about your experiences in interdisciplinary work. How big is the share of interdisciplinary work in your daily working life? (i.e. in percent or number of projects in the last year)
  Which tasks or roles do you take in interdisciplinary work? (leadership experience?)

Current situation and behavior (1)

- Introduction
  *We will now focus on typical work situations, in which differences between more and less interdisciplinary competent individuals emerge. We want to collect situations in which you or individuals in your work environment have effectively or ineffectively coped with the demands of interdisciplinarity. It is especially important for me to know **how** the individuals have behaved as we want to derive demands from the behavior they displayed. Do you have any questions?*
- Instructions and leading questions
  Let's revisit the past year: Do you remember a situation that you have witnessed or experienced yourself in which somebody has collaborated particularly well with another person from a different discipline?
  Let interviewee talk. Than inquire.

Assistance: *Think of a successful collaboration project. Typical situations? Meetings? Situations, in which a project / a collaboration "hung on the balance"?*
When no answer follows: *What experiences have you made with professionals from other disciplines during your career? Is interdisciplinarity important in this field?*

- Situation

  How did this situation come about? Please describe it precisely, so that I can imagine it like in a movie.

  - *What was your share in the occurrence of the situation?*
  - *I would like to get a more detailed idea of how…*
  - *You have just said that… Can you specify this?* or *How did this happen?*
  - *How exactly did the situation go?*
  - *Who was involved in the situation?*
  - *What was the result?*
- Behavior

  What exactly did the acting person do in the situation?
  - *What did you do? What did the others not do?*
  - *What did you not do that the others did?* (or vice versa)

    What alternative positive behavior could the acting person have displayed?

  What shouldn't the acting person have done under any circumstances? What are especially negative behaviors in this context?
  Why do you think this behavior is relevant for interdisciplinary teamwork?
- Result of the situation:

  How did the situation end?
  - *What were the results?*
  - *How did the environment react?*
  - *What were the consequences for the environment / the situation?*
  - *What have you learned from the situation yourself? What is your personal conclusion?*
  - *What would you do differently today?*

Current situation and behavior (2)

- Instructions and leading questions

  Thank you very much! Can you recall another typical situation that you could describe? Unfortunately interdisciplinary work is not always smooth. Maybe you have experienced a difficult situation that you could share?

  Let interviewee talk. Than inquire.

  When no answer follows: *What experiences have you made with professionals from other disciplines during your career? Is interdisciplinarity important in this field?*

- Situation

  Have you recently thought about someone that he or she is well suited for interdisciplinary work?
  What exactly happened to give you that impression?
  How did this situation come about? Please describe it precisely, so that I can imagine it like in a movie.
  - *What was your share in the occurrence of the situation?*
  - *I would like to get a more detailed idea of how…*
  - *You have just said that… Can you specify this?* or *How did this happen?*
  - *How exactly did the situation go?*

  - *Who was involved in the situation?*
  - *What was the result?*
- Behavior
  What exactly did the acting person do in the situation?
  - *What did you do? What did the others not do?*
  - *What did you not do that the others did?* (or vice versa)

  What alternative positive behavior could the acting person have displayed?
  What shouldn't the acting person have done under any circumstances? What are especially negative behaviors in this context?
  Why do you think this behavior is relevant for interdisciplinary teamwork?

- Result of the situation:
  How did the situation end?
  - *What were the results?*
  - *How did the environment react?*
  - *What were the consequences for the environment / the situation?*
  - *What have you learned from the situation yourself? What is your personal conclusion?*
  - *What would you do differently today?*
  - *Is this situation specific to your area of expertise or do you think that it could apply to others as well?*

<u>Ending the interview</u>

We have now discussed various situations that may arise in interdisciplinary collaborations. With the help of this information we will derive certain demands in the next step. In my view, we have discussed all aspects necessary for this.

- Questions:
  In your opinion: Is there anything else you would like to add?
- Thanks for participation
- Preview on further investigation steps:
  In a next step, the situations and behaviors you described will be assigned to categories, from which a model for interdisciplinary competence is derived.
  Are you interested in the results of this work? If so, I would send you a summary by e-mail early next near.
- Farewell

Interview Protocol for Datasource 2

Welcome and Warm up

- greeting
- Introduction of the interviewer
    - Reference to previous contact (cover letter/telephone call).
- Thanks for willingness to talk
  Thank you for taking the time to talk to me.
- Information on the purpose and content of the requirements analysis
  As already mentioned, the aim is to develop a requirements profile for the positions of engineering and natural science graduates at your institute / in your company. We want to find out which of these requirements differentiate between scientific and industrial jobs. For this purpose, we conduct interviews with job holders in science and industry, or their supervisors.
- *The entire requirements analysis consists of three steps. Today, in the first step, I will ask for work situations, in which high-performing and low-performing job holders differ in their behavior. In the next step we group these behaviors into requirements. In the third and final step, the result will be presented to you for examination in the form of a short online questionnaire.*
- Overview of the interview topics:
  For today's first step in the requirements analysis, I would first like to talk to you about the tasks of the job holder. Our discussion will focus on the behaviour of high-performing and low-performing job holders in various work situations. I would also like to talk to you about possible future tasks for the job holder.
- Information on the format of the interview:
  During our conversation, I will follow a protocol. Just so I don't forget anything and to be able to do all the interviews in the same form.
- Information about the amount of time:
  As already mentioned, we will require about 45 minutes for the interview.
- Permission to record the conversation:
  I would like to record our conversation in order to concentrate better on the conversation and not lose any information by writing it down. Do you agree to a recording? Thank you very much.
- Explanation of data protection:
  All contents of our conversation are of course subject to data protection. I will keep all data strictly confidential in accordance with the requirements and for your protection. A central component of this transcription is anonymization of the data. This has the consequence that a link between the contents of the interview and your person is only possible by non-electronic means and only through me.
- *Do you have any questions?*

PART I: DESCRIPTION OF WORK ACTIVITY

Tasks

- Introduction:
  I would like to ask you to describe the job holder's area of activity so that I can get a first impression of the position.
  Let them talk, inquire if necessary

Qualification and knowledge requirements

- *What are the basic qualifications required for the position?*
  Which academic subject?
  Which specialization?

PART II: SURVEY OF SITUATIONS AND BEHAVIOUR (1)

- Introduction:
  Now you've told me about the job owner's duties. Let us take a closer look at typical and everyday work situations in which there are differences between high-performing and low-performing job holders. I would like to collect with you that kind of situations, which were mastered well or less well by job holders. It is of particular importance to me how the job holder has behaved in the respective work situation.
  Do you have any questions?
- *Let's just go back to the past year. Do you remember a situation that you experienced yourself or observed and that was handled particularly well by a job holder?*
  Let them talk, then ask questions
  - Assistance if the interviewee cannot think of anything:
    Think of something you've done lately you've been proud of.
    Do you remember a day when you were particularly effective? What did you that made you so effective?
- *Unfortunately, one is not exclusively confronted with a sense of achievement at work. Do you remember a situation that you experienced or observed and that was handled particularly badly by a job holder?*
  Let them talk, then ask questions
- *Remember when you saw someone doing something with regard to the job and thought to yourself, "If I were in that situation, I would act differently." What did you see?*
  Think of mistakes you saw in others who were new to the job.
- Situation:
  - *How did this situation happen?*
  - *What was your contribution to the situation?*
  - *What happened then in detail? Could you please tell me so I can imagine it like in a movie?*
  - *I would like to get an exact picture of how...*
  - *You said before that ... Can you elaborate on that?* or *How did this happen?*
  - *How exactly did the situation occur?*
  - *Who was involved in the situation?*
  - *What was the result of the situation?*
- Behavior:
  - *What exactly did the job holder do in the situation?*
  - *And how did he proceed in detail?*
  - *What did you do? And what did the others?*
  - *What didn't you do what the others did (and vice versa)?*
  - *How else could the job holder have behaved positively in the situation?*
- Result of the situation:
  - *How did it end then?*
  - *What was the result?*
  - *How did the surroundings react?*
  - *Which consequences did this have for the surroundings / situation?*

Query further situations according to the same scheme

CONCLUSION OF THE CONVERSATION

- *We have now talked about many situations that job holders have to deal with. This information is now used to derive requirements in the next step. In my view, we have discussed all the essential aspects of this.*
- *In your opinion, is there anything else you would like to add?*
- *Thank you for your participation*
- Outlook on further investigation steps:
  In the next step, the situations and behaviors you describe are assigned to requirement categories, from which the requirement profile is then formed. The result will then be presented to you for examination in the form of a short online questionnaire.
- *Do you have any questions?*
- Farewell

Supplementary Table 1

Summary of critical incidents and deduced behaviors from the interview study

Incident	Summary of incident	Positive indicators	Negative indicators
1	Limited resource conflict in an interdisciplinary research institute. The opposing department head tried to find a compromise between conflicting interests and started by listening and trying to understand the needs of both parties.	Listened, argued for his point of view, for him it was clear that an agreement had to be found, accepted the premise, consensus-orientation	Questioning others research methods, trying to
2	Conference on engineering education. Interdisciplinary field with researchers from different disciplines. One presentation dealt with a study on student motivation; however the operationalization was faulty according to the informant. Difficult situation: how to uphold own quality criteria without to condemn procedures from other disciplines.	Uphold own quality criteria, be an expert in one's own discipline, define common quality criteria, ask a lot, explain critical aspects, make suggestions for improvement	Condemn what others do, judge from own perspective
3	Progress report for an interdisciplinary project of engineers and educational scientists is due. The proposal has been rather vague, without clear milestones. For educational scientists it seemed as if engineers did not reach goal. Engineers interpreted goals differently and thought they met the expectations. Discussions were heated and included many silent reproaches.	Define goals clearly, put agreements in a written form, keep updated to understand who does what and detect problems and misunderstandings early	Make silent reproaches, heated discussions, discuss unrelated (political) aspects at the same time
4	Process manager needs to manage many different stakeholders from various departments and disciplines. In a meeting, the assembly team tells that piping won't be finished as planed and blames other groups. The process manager structures the process, collects information and finds solutions between rivaling disciplinary interests.	Accept responsibility, moderate, collect facts, structure information, find partial solutions,	Pass the buck to someone else, blame others
5	Team member is sent to represent his department in an interdisciplinary team responsible for bringing a new product on the market. The team describes process and needs to allocate areas of responsibility. Everyone tries to make other departments	Explain options, describe expertise, take the other's perspectives into account	Take responsibility for all the tasks, make other departments do own work

Incident	Summary of incident	Positive indicators	Negative indicators
	do more tasks. Acting person describes and explains what his department is able to do and what information is needed for that, explains what's outside of their expertise.		
6	Process manager needs to organize the construction of a new plant. Engineer requests information on distillation temperature and gets a short reply. Pipeline was built to demands of distillation temperature, although the necessary transport temperature is much lower. High expenses.	Giving context information, asking for context information, perspective-taking	Lack of interest, lack of initiative
7	A new column is brought into service. The planning team is very content. Workforce is rather unhappy due to practical discomfort while using various parts. Project manager did not expect that and needs to be involved more with workers and their needs in everyday work.	Be involved with everyday work of employees, job shadow, simplify information for workers, focus on most relevant features	
8	Project cooperation of engineers of different disciplines and universities on a complex tool concept. One side was very detail oriented, while the other was on a high level of abstraction. Meetings were not successful, as people were not on the same page or level of abstraction.		Lose track of meta-level, communicate on different levels, act very dominant in meetings
9	As part of an interdisciplinary project, the team needs input from an external expert. That didn't work. Several emails were not answered. The acting person didn't give up and kept asking the expert. The project was not highly prioritized for all involved.	Find new words to explain, keep asking to get necessary information	Give up, impute bad intentions
10	In a project proposal for a financing institution, a sales person accidently gave false information. The involved consultant was very upset and corrected the sales person immediately. Afterwards the consultant spoke alone with the client and did not allow any more involvement of the sales person.	Show appreciation for different team members, forgive mistakes	Working alone to avoid problems
11	Big research cluster with many project from different disciplines: The management decided to have teams create short video clips to describe their research project, goals and methods. The team met regularly to develop a script and discuss their processes and	Initiate mutual introductions, condense information for others	

Incident	Summary of incident	Positive indicators	Negative indicators
	goals. Important to be able to describe one's own research to others.		
12	Transdisciplinary project in a distant cooperation. Goal: develop a lifeline with sensors for fire fighters. One project partner developed the lifeline, the other the sensors. After months of separate work, partners meet and show their prototypes. The lifeline was too thin to fit the sensors. Afterwards people laughed it off and decided to talk and meet more	Call and talk between meetings, be as concrete as possible, show what you do	Talk in abstract ways
13	In an engineering company, employees criticize a database of quality management documents used by different departments. An IT employee takes over and discusses with the departments about their needs and problems. He developed a plan and got all necessary persons involved. He made a suggestion on how to split costs between departments and explains how the budget will be used.	Have everyone explain situation from their point of view, include all persons necessary, split costs fairly, develop plans, ask for feedback, manage expectations	Favor own department / discipline
14	In a mechanical engineering company, order processing worked by fax or mail also order confirmations were manually processed. Thus, they planned to create a new electronic interface. The programmer had long discussions with the suppliers to agree on interfaces. After a year, only 3 of 40 suppliers were connected in the system. The programmer said his interface works but the problems are caused by the suppliers. Project was done, but without any benefit. It would have been better, if the programmer had taken care of the entire project.	Take responsibility, involve other parties, pursue goals, integrate different aspects, take ownership	Blame others, wait for others to act, lack of prioritizing, lose goals out of sight
15	People from production, planners, architects and management sit together to plan a factory. Planning errors, delays and costly changes can happen here. The solution: a factory planning table. That is a tool with a large touch screen where the factory is visualized, so one can quickly integrate people from different disciplines and work together. Pervious solutions required a lot of	Make complex information vivid, visualize, find technical solutions to bridge disciplinary gaps	

Incident	Summary of incident	Positive indicators	Negative indicators
	knowledge on the issue. At first, most people were skeptical, but the success is growing and everyone is positive.		
16	Tough issue regarding the reorganization of a maintenance area: The area was too big and had to be downsized. Employees had to move into construction, which was problematic because they were overqualified. The partner involved put himself into the shoes of the employees: “we maintenance specialists know”, “I as a maintenance engineer”. He managed to be accepted and to explain the necessity. Employees then have supported the painful process.	Explain necessities, take over other perspective and also language, jointly look for solutions, connect to the group as a whole verbally	Impress one’s own perspective on others
17	After completion of the planning phase of a large-scale project in the field of plant engineering, the acting person has been involved in the implementation with representatives of many external companies, which are not all academics (for example craftsmen). At first, she had always tried to convince them with scientific arguments or in the language of project management. Over time, however, she has learned that she has to change when she is on the construction site: use more authoritarian language, maybe even swear in order to direct the workers effectively.	Change language to adapt to audience	Convince craftsmen with scientific arguments, address audience inadequately
18	Department, whose employees have different backgrounds regarding discipline and qualification level. There are also a number of differences in the way employees work, but most of the employees are highly qualified academics, who are mostly self-motivated. There are also employees who need precise guidelines to carry out a task on time. It is necessary for the department head to deal with each employee in a very individual way, because some of them make too high demands on themselves and others have difficulties in showing initiative and making decisions.	Get involved with each employee individually, deal with particularities	
19	A mechanical engineer conducts a joint project with sociologists and economists. In the corresponding discussions between the project members, it becomes clear how different the disciplines	Open oneself for arguments of other disciplines, be cautious in	Lack of appreciation of other disciplinary methods, lose own methodology out of sight

Incident	Summary of incident	Positive indicators	Negative indicators
	methodically approach a topic. The members have prejudices against the other methods: "What you do is not research, just trial and error. This is like tinkering!" The acting person manages to open up to the arguments of the other disciplines without losing sight of her own methods. Also others start to use some of her ideas and methods.	discussions, express mutual appreciation	
20	The acting person is very good at looking at problems from different perspectives and disciplines. He is open to other disciplines and can therefore recognize that many questions are very complex and can not only be viewed from a particular perspective. Also he is able to communicate effectively with employees of other areas and to respond flexibly to different conversation partners.	Consider problems from different perspectives, adjust flexibly to different audiences	
21	Although she is not a lawyer herself, the acting person likes to deal with legal texts and can also understand them in terms of content. She can then convey the contents of the legal texts to colleagues. She likes to communicate with and interpret between authorities, lawyers and colleagues.	Interpret between different disciplinary perspectives	Dislike contact with other people
22	The acting person often cooperates with employees of other departments. This is not always easy, as each discipline has a different focus. She avoids conflicts in such situations by keeping an open attitude and, at the same time, signaling that she takes the different methods and views seriously. She also tries to adjust language to her counterpart and to explain things patiently	Adjust language, take different methods and ways seriously, be patient in explaining	
23	A programmer is asked to design a database to capture data content. Originally, a central solution was planned, which however would lead to a time delay due to the extended workload. To counteract this problem, the acting person takes the initiative and instructs her colleagues. She encourages the programmer to include the core elements first, so that at least a basic version is	Take initiative to implement a quick solution, be clear in goals and priorities	

Incident	Summary of incident	Positive indicators	Negative indicators
	available. This then needs to be explained to the employees of different disciplinary backgrounds.		
24	When it comes to working together, especially when different disciplines come together, the acting person focuses on capturing the emotional level. She is not concerned with presenting herself, but she can adjust herself to different people and likes to listen. She takes up the desires and problems of others and processes them. This often results in solutions for her own problems.	Take emotional aspects into account, incorporate desires and problems of others	
25	The acting person works in an area that is not specific to a discipline. It is important for her to deal with people from many different disciplines. She is able to absorb and understand a great deal of knowledge from related disciplines. This allows her to complete her own tasks successfully.	Integrate and understand knowledge from related disciplines	
26	A project leader who is responsible for building a plant has to think interdisciplinary. One has to master the system technically, one has to get material on budget, consider regulations and build it in a way workers will be able to use it. An engineer needs to keep that in mind, otherwise he will build the best plant from an engineers' view, which will never run in practice.	Be a generalist, keep in mind the entire project	Be too much of a specialist
27	In the industry the trend is the matrix organization. That is, there is a hierarchy, but for certain topics teams are build. This requires one to work with people from different backgrounds. One has to deal with different stakeholders, team members, employees and managers. One needs to enforce the own interests.	Enforce own interests, question oneself, change on different levels of abstraction quickly	

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Supplementary Table 2

Study 2: Factor Loadings for Exploratory Factor Analysis with Geomin Rotation of Initial 61-Item Set and Interest

Item text	Initiative for Exchange and Knowledge Integration	Interest and Appreciation	Target group-specific communi-cation	Appreciation	Reflection
[02] Often, I am the person who has the ideas for interdisciplinary projects.	**.57***	.16*	-.11	.08	.01
I am good at pushing an interdisciplinary work group that is held up.	**.52***	.04	.34*	.02	-.06
[08] In interdisciplinary work, I am good at connecting and integrating knowledge from different disciplines.	**.52***	.11	-.03	.14	.32*
[01] It is easy for me to make specific suggestions in order to create a basis for discussion in an interdisciplinary team	**.51***	-.04	.22*	.06	.13*
[03] It is easy for me to take the initiative in an interdisciplinary meeting.	**.48***	-.09	.25*	-.02	.04
If I notice that we are talking at cross-purposes I can easily intervene.	**.45***	.01	.15	-.02	.15*
[09] In interdisciplinary teams, I succeed in connecting different disciplines content-wise.	**.42***	.08	-.10	.31*	.27*
My goal is to truly understand what the other members in an interdisciplinary team do.	.03	**.62***	.15*	-.02	.07
In interdisciplinary teams, I seriously try to understand other disciplines' methods.	-.03	**.56***	.07	.07	.09
In interdisciplinary teams, I invest time and effort in understanding the ways of thinking and the approaches of other disciplines.	-.07	**.51***	.06	.03	.14*
[i] The possibility to work interdisciplinarily contributes to my work satisfaction.	.22*	**.50***	-.08	.38*	-.03
It makes me curious if I hear about methodological details of other disciplines.	.07	**.48***	-.03	.11	-.10
I am willing to accept additional work and expenses caused by interdisciplinarity.	.11	**.47***	-.05	.30*	.07
[i] It tempts me to work with people from other disciplines who have a completely different approach to things than I have.	.06	**.44***	.01	.35*	.04
If planning interdisciplinary problems, I ask for practical examples to understand why the other discipline works the way it does.	-.07	**.44***	.19*	-.08	.14*
[i] The possibility to do interdisciplinary work inspires me.	.26*	**.43***	-.08	**.41***	.03
In discussions, I gently treat people from other disciplines.	.02	**.41***	**.46***	-.07	.10

Item text	Initiative for Exchange and Knowledge Integration	Interest and Appreciation	Target group-specific communi-cation	Appreciation	Reflection
[06] It is not a problem for me to adapt my language so everyone in an interdisciplinary team understands.	-.02	.02	**.57***	.08	.13
In interdisciplinary collaborations, I easily strike the right note.	.19*	.11	**.51***	.02	.08
In interdisciplinary teams, I am good at starting at other disciplines' level regarding language.	.10	.02	**.50***	.08	.28*
I'm quick to realize how to explain something to members of different disciplines.	.12	.16*	**.49***	-.10	.17*
[04] In interdisciplinary teams, it is difficult for me to avoid unnecessary technical terms.	-.09	-.15*	**.47***	.16	.01
During a first meeting, it is easy for me to understand the goals and needs of my interdisciplinary conversational partner.	.37*	.12	**.42***	-.01	-.04
[05] In interdisciplinary teams, I find it difficult to get my point across.	.12	-.15*	**.41***	.19*	.19*
In most cases, interdisciplinary teams do not provide additional value.	-.02	.06	.03	**.63***	.03
I often think that a team with members only from my own discipline would work at least as well as an interdisciplinary team.	.04	.11	-.02	**.56***	.05
I am often struggling to see how the input of other disciplines in enriching for the interdisciplinary team.	-.12	.14	.06	**.54***	.06
At the beginning of collaborating with other disciplines, I wait to see how motivated the other team members really are.	-.02	-.24*	.21	**.51***	-.01
[13] I can very precisely name the methodological and content-related features of my discipline.	-.08	-.02	-.05	-.02	**.83***
[12] I can very precisely name the questions my discipline is in charge of and how my discipline differs from others.	-.00	.01	.00	-.07	**.71***
[11] I uphold the quality criteria of my own discipline in interdisciplinary teams.	-.07	-.02	-.02	.02	**.46***
I explain to members of other disciplines the special competences of my discipline.	.08	.24*	-.03	-.11	**.43***
I find it hard to explain my own topics to other people.	.07	-.18*	.21*	.21*	.38*
In interdisciplinary teams, it is easy for me to give other members insights into my own discipline.	.12	.05	.31*	.07	.37*
I am good at explaining the content of my work to others.	.08	-.01	.23*	.11	.36*
I can clearly recognize the limits of my own discipline.	.10	.12	.06	-.03	.34*

Item text	Initiative for Exchange and Knowledge Integration	Interest and Appreciation	Target group-specific communi-cation	Appreciation	Reflection
In interdisciplinary teams, I can easily follow what others are currently working on.	.21*	.13	.17*	.06	.28*
I repeatedly explain my topics to members of other disciplines without growing impatient.	-.14	.17*	.23*	.18*	.27*
[10] In interdisciplinary teams, I can easily comprehend the contents of other members' work.	.36*	.06	.02	.11	.26*
Whenever I hear something new from a different discipline, I find it hard to build connections to my own knowledge.	.27*	-.07	.02	.29*	.25*
[07] Regarding language, I find it hard to engage with team members from different disciplinary backgrounds.	-.10	-.05	.34*	.22*	.24*
It is easy for me to reflect upon my own discipline.	.21*	-.02	.14	.04	.23*
In interdisciplinary teams, I ask for contextual information to learn more about other disciplines.	.22*	.39*	.07	-.08	.22*
In interdisciplinary teams, I struggle to recognize emotional or subtle aspects of communication.	.33*	.04	.33*	.17*	-.20*
If working interdisciplinarily, I invest time and effort to develop a common understanding of our task.	-.04	.26*	-.04	.08	.20*
Due to their methods and research questions, there are disciplines that I cannot take seriously enough to work with them.	.01	.18*	.22*	.30*	-.17*
I am good at developing common quality standards with interdisciplinary peers.	.39*	.16*	.23*	-.15*	.17*
In interdisciplinary teams, I find it difficult to make precise and constructive proposals.	.36*	-.10	.19*	.08	.17*
I am good at recognizing what other disciplines might bring to a shared project.	.31*	-.04	-.03	.37*	.17*
Sometimes it is a waste of time to explain my own work in detail to people from other disciplines.	-.02	.08	.17*	.37*	-.12
In interdisciplinary teams, I am willing to lower my quality standards.	.04	-.11	-.05	.23*	.11
In interdisciplinary teams, I promote an active exchange.	.23*	.37*	.10	.12	.11
If working interdisciplinarily, I find it hard to detect implicit meanings.	.15	-.04	.38*	.12	-.09
In interdisciplinary teams, I can easily follow other disciplines' lines of argumentation.	.37*	.20*	-.01	.03	.07
I can easily accept other disciplines' propositions and demands.	.05	.20*	.12	.29*	.06

Item text	Initiative for Exchange and Knowledge Integration	Interest and Appreciation	Target group-specific communi-cation	Appreciation	Reflection
In interdisciplinary teams, I try to avoid sharing my ideas, thoughts, and plans before others do.	.18*	-.15*	.17*	.34*	.06
I think it is best if interdisciplinary teams work in disciplinary subgroups and then combine the results.	-.06	-.03	-.05	.32*	-.05
In interdisciplinary teams, I am good at adapting to others' communication styles.	.35*	.10	.22*	.14*	.04
I motivate others to get involved in interdisciplinary collaborations.	.33*	.30*	.10	.18*	.03
If working interdisciplinarily, I avoid using special terms that other disciplines might not be familiar with.	-.13	.16*	.30*	-.06	.03
In interdisciplinary teams, I find it hard to cognitively engage with other perspectives.	.24*	.11	.16*	.29*	.02
It is hard for me to accept that interdisciplinary projects imply more effort than collaborations within my discipline.	.14	.23*	.19*	.32*	-.02
I find it difficult to wait and see what happens in interdisciplinary teams.	.16	-.11	-.33*	-.13	-.01
[i] I want to do more interdisciplinary work	-.03	.39*	.07	.25*	.01

Note. Factor loadings > .40 are in boldface. * $p < .05$. Items that have been included in the final item set after several iterations are marked with their final item number, [i] refers to the final interest items.

Supplementary Table 3

Study 3: Correlation table

	Measure	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.
1.	Initiative for exchange	-	.26***	.54***	.27***	.50***	.52***	.35***	.52***	.53***	.52***	.34***	.25***	.47***	.06	.26***	.27***	.22**	.19***	.15
2.	Target group-specific communication	.24**	-	.32***	.19***	.23***	.22***	.27***	.17***	.15***	.24***	.25***	.16***	.21***	.18***	.08	.25***	.06	.31***	.14
3.	Knowledge integration	.53**	.31**	-	.37***	.48***	.47***	.46***	.41***	.39***	.49***	.41***	.20***	.50***	.17***	.22***	.36***	.23**	.32***	.19*
4.	Reflection	.25**	.18**	.34**	-	.25***	.24***	.29***	.19***	.18***	.28***	.11*	.06	.27***	.05	.13**	.24***	.02	.09	.05
5.	Conflict resolution	.33**	.22**	.37**	.19**	-	.92***	.85***	.81***	.82***	.96***	.39***	.33***	.55***	.11*	.16***	.34***	.20*	.22***	.26***
6.	Collaborative problem solving	.43**	.11*	.33**	.17**	.54**	-	.70***	.95***	.92***	.94***	.38***	.34***	.55***	.14**	.17***	.34***	.19*	.20***	.25***
7.	Communication	.23**	.21**	.31**	.24**	.38**	.31**	-	.49***	.48***	.85***	.37***	.30***	.45***	.13**	.11*	.33***	.12	.24***	.23**
8.	Goal setting and Performance	.41**	.09*	.25**	.12*	.38**	.47**	.18**	-	.98***	.86***	.34***	.31***	.52***	.12*	.18***	.30***	.18*	.16***	.21**
9.	Planning and task coordination	.44**	.14**	.36**	.17**	.44**	.56**	.21**	.60**	-	.86***	.33***	.30***	.51***	.10*	.18***	.28***	.19*	.16***	.20*
10.	Meeting management	.26**	.21**	.33**	.24**	.38**	.36**	.33**	.37**	.36**	-	.41***	.36***	.57***	.14**	.17***	.36***	.16*	.22***	.25**
11	Interest in interdisciplinary work	.30**	.19**	.36**	.07	.28**	.26**	.22**	.17**	.26**	.19**	-	.51***	.45***	.28***	.22***	.45***	.13	.49***	.18*
12.	Preference for teamwork	.23**	.14**	.19**	.07	.25**	.24**	.21**	.23**	.27**	.19**	.45**	-	.52***	.16**	.14**	.27***	.09	.31***	.15
13.	Teamwork self-efficacy	.47**	.23**	.51**	.27**	.43**	.46**	.33**	.36**	.49**	.31**	.40**	.55**	-	.10*	.19***	.30***	.21**	.30***	.27**
14.	Managerial support	.03	.18***	.16***	.04	.07	.04	.11*	.06	.13**	.12*	.21***	.16***	.13**	-	.14**	.42***	.16	.40***	.21*
15.	Task interdependence	.25**	.09	.21**	.13**	.08	.17***	.07	.10*	.17***	.10*	.20***	.15***	.18***	.16***	-	.25***	.13	.13**	.11
16.	Team effectiveness (self)	.22***	.26***	.32***	.24***	.27***	.25***	.27***	.16***	.29***	.24***	.35***	.28***	.32***	.43***	.23***	-	.23**	.60***	.29***
17.	Team effectiveness (peer)	.18*	.08	.24**	.01	.17*	.20*	.01	.15	.12	.17*	.16	.08	.23**	.18*	.10	.21**	-	.26***	.59***
18.	Satisfaction with team (self)	.17***	.32***	.31***	.09*	.18***	.17***	.18***	.09	.14**	.18***	.44***	.32***	.33***	.40***	.15**	.61***	.25**	-	.32***
19.	Satisfaction with team (peer)	.12	.15	.20*	.03	.24**	.21**	.17*	.11	.17*	.15	.16*	.16	.30***	.18*	.10	.28***	.60***	.32**	-
	M	4.38	4.80	4.81	5.01	4.94	4.73	4.71	4.44	4.83	4.84	4.51	4.67	4.99	4.99	4.55	4.77	5.01	5.02	5.38
	SD	.92	.83	.74	.78	.68	.81	.71	1.00	.87	.72	1.02	1.09	.71	1.17	1.13	.86	.69	.91	.74

Notes. N = 447, correlations between manifest variables are shown below the diagonal, correlations based on factor scores are shown above the diagonal.
*$p \leq .05$; ** $p \leq .01$; *** $p \leq .001$.

Appendix B: Supplementary Material to Manuscript III

Interview Manual for Interviews with Academic ounselors

- We would like to get to know your study program. The study program is advertised as being interdisciplinary in the program description, and this is what we are interested in. We want to understand how interdisciplinarity is included in the program, because there are so many different ways on how to accomplish interdisciplinarity.
- First of all, I would like to know if you would describe the program itself as interdisciplinary.
    - ... If so, can you explain why?
    - If not, what would you say what is missing to call it interdisciplinary?
- How is the interdisciplinarity of the program discussed with the students? For example, do you actively communicate about interdisciplinary challenges, in the courses, in assemblies….
- How do your current students perceive the study program?
  Do you have the impression that interdisciplinarity is a topic among the students?
- In your opinion, what role does interdisciplinarity play for prospective students?
  Do you have the impression that their interest is due to the interdisciplinary nature of the program?
- In order to achieve an integration of the participating disciplines and synthesis of knowledge, there are various methods that are cited in current literature that are being applied in the practice of some interdisciplinary degree programs. We will now talk about some of these teaching formats and whether or not they play a role in your study program.
    - Team teaching, in which lecturers with different disciplinary backgrounds give a course together and teach from their respective background
    - lecture series where lecturers from different disciplines serially present one and the same topic from their point of view
    - Project seminars
    - Colloquia
    - lab studies in which contents of various disciplines are combined
- Is something like the aforementioned or something similar offered in your study program?
- Are there specific courses in which you think the interdisciplinary nature of the program is particularly evident?

- Do some courses or events take place at other institutes / faculties?
    - And if so, do students attend lectures that are also being attended by students from other degree programs, or are these courses offered specifically for your program by the external faculty?
- If you had to estimate / roughly figure out how many of the 180/120 credit points a student needs to achieve in your degree program, what is the least and highest amount that can be achieved by completing interdisciplinary modules?
- Are there opportunities outside the curriculum to create integration of the subject disciplines?
    - If yes, which?
- What would you say are the key challenges in your interdisciplinary study program?
- With that I would have reached the end of my questions.
  Thank you for taking the time!
  Would you like to add something else?