The relationships between professional development, new technologies and changes at work

How professionals adapt to changes at work by engaging in professional development

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Technology is neither good nor bad; nor is it neutral.
—Melvin Kranzberg (1986, p. 545)

But the real question is not whether machines think but whether men do.
The mystery which surrounds a thinking machine already surrounds a thinking man.
—B. F. Skinner (1969, p. 288)

Summary

As technological change continues to reshape work in many sectors, there is a clear need to understand how professionals respond and develop in the face of these changes – a question that existing research has yet to fully address. This dissertation addresses this gap by answering the research question: How do different types of new technologies impact work characteristics and professional development, and how do changes in work characteristics relate to professional development and its associated work outcomes? To investigate this question, three complementary empirical studies were conducted: a systematic review of evidence in the field, an in-depth qualitative interview study in the financial sector, and a quantitative survey study in the financial sector.

Across these studies, the relationships between new technologies (i.e., task-supporting, task-replacing, and communication technologies), changes in work characteristics, aspects of professional development (i.e., elaboration, expansion, and externalisation), individual characteristics (i.e., occupational self-efficacy and technological acceptance), and key work outcomes (i.e., organisational commitment, job satisfaction, and emotional exhaustion) were systematically examined.

The first major finding is that the types of new technologies are likely to be systematically associated with distinct aspects of professional development. Task-supporting technologies were found to foster the refinement and adaptation of established routines (i.e., elaboration), while task-replacing technologies were most strongly linked to the active pursuit and acquisition of new knowledge and skills (i.e., expansion). Communication technologies, by contrast, primarily facilitated the sharing and dissemination of expertise within and between teams (i.e., externalisation). These findings suggest that the functional characteristics of different technologies play a key role in shaping how employees engage in professional development in response to technological change.

A second important contribution lies in demonstrating that new technologies change work characteristics along certain dimensions of change, including direction (i.e., increase or decrease) and intensity (i.e., the magnitude of change). The combination of qualitative and quantitative data enabled the identification of relevant work characteristics and a synthesis of changes in work characteristics into overarching themes, thereby highlighting the complex and interrelated ways in which employees experience and respond to technological developments in their workplace. These results illustrate the nuanced pathways through which the engagement in professional development is prompted by new technologies and changes at work. Additionally, the dissertation examined work outcomes related to professional development as well as individual characteristics that may affect professional development. The analyses provided limited evidence that individual characteristics may moderate the relationship between new technologies and change at work with professional development, and the relationships between professional development and work outcomes such as affective commitment were found to be complex.

The final contribution lies in the critical appraisal of the conceptual, methodological, and domain-specific choices undertaken throughout the research, underscoring both the contributions and the limitations of the current approaches. In particular, the studies highlighted the importance of using longitudinal and multi-method designs to better capture the evolving nature of work, new technologies, and learning. The exclusive focus on the financial sector also calls for future research to examine the generalisability of findings across other professional domains.

In summary, this dissertation provides empirical and conceptual groundwork for understanding the intricate interplay between new technologies, changing work characteristics, and professional development in contemporary organisations. While several open questions remain, these findings lay important groundwork for future studies and action in practice in the context of ongoing changes at work due to technological developments.

1 Technological developments and their impact on work

Contemporary professional environments are undergoing profound transformations, driven primarily by rapid technological advancement (Cascio & Montealegre, 2016). Nowadays, in particular, the emergence of disruptive technologies – such as artificial intelligence (AI) – is reshaping operational structures, communication patterns, and decision-making processes across multiple fields (Neiroukh et al., 2024). These innovations do not unfold in isolation; rather, they are interacting with escalating geopolitical tensions, environmental issues, and demographic challenges that undermine established frameworks of global cooperation and call into question prevailing assumptions about technological governance (Chari, 2025). Furthermore, the COVID-19 pandemic marked a significant inflection point by accelerating the widespread adoption of digital tools, radically altering conventional work practices and highlighting both the potential and the vulnerabilities of digitally mediated work environments. Taken together, these developments compel a critical reassessment of traditional models for vocational education and training and call for fresh theoretical and methodological approaches to understanding how employees can keep adapting to the evolving nature of work.

Against this backdrop of rapid technological developments, it becomes essential to define clearly what is meant by "technologies." For the purpose of this thesis, technologies are defined as digital or mechanical tools, devices or systems capable of replacing or supporting work tasks (McOmber, 1999). New technologies complement work tasks or substitute work tasks (Autor et al., 2003), while being embedded in the social context physically (e.g., posing the need to be used for certain tasks due to for instance regulatory reasons) as well as functionally (e.g., by providing new possibilities for interaction) (Mulder et al., 2022).
As such, new technologies hold the potential to change central characteristics of work across industries and professions, often subtly but sometimes with dramatic immediacy, thus shifting what is required of workers in order to perform effectively (Cascio & Montealegre, 2016).

In this volatile environment, the capacity to respond proactively – by developing one's own professional competences – has emerged as a foundational skill for sustained employability and career adaptability (cf. Donald et al., 2023; Otoo, 2019). Employees must learn to adjust their professional competences (i.e., integrated chunks of knowledge, skills and attitudes; Ellström, 1997) required to perform work effectively in alignment with changing demands.
This ongoing process of developing one's competences at and through work is called professional development (Simons & Ruijters, 2004). Professional development is a dynamic and ongoing process, shaped by the evolving nature of work, and in turn shaping how work is carried out (cf. Hager, 2011). Drawing on the framework by Simons and Ruijters (2004), professional development consists of three interrelated aspects that reflect specific learning activities: elaboration, expansion, and externalisation. Elaboration refers to learning through critical reflection on one's own practical experiences; expansion involves the active

integration of new ideas, information or concepts; and externalisation encompasses learning through meaningful contributions to shared knowledge and collective practice.

Understanding how employees engage in these forms of professional development in response to changes at work is not merely a matter of academic interest but a societal and organisational necessity. On one level, fostering professional development is key to organisational resilience: it ensures that individuals remain capable of navigating complexity and contributing productively amid changing roles and responsibilities (Pan & Seow, 2016). On another level, it holds deep relevance for workers themselves, as the ability to develop, apply and adapt competences has been linked to a range of positive work outcomes, including job satisfaction, organisational commitment and overall wellbeing (e.g., Theorell, 2020). In a world where uncertainty about the future of work is not just present but accelerating, cultivating conditions that support professional development is one of the most strategic levers available for organisations seeking to thrive, and for individuals striving to remain healthy, happy, and engaged.

Yet, despite the increasing urgency of understanding how professional development emerges in the context of changes at work due to new technologies, current academic literature leaves several important questions unanswered. While the disruptive potential of new technologies at work has been widely acknowledged, the evidence base remains fragmented and incomplete, and the role of professional development is widely disregarded. Two critical gaps persist in the research landscape that this thesis seeks to address:

Research on the effects of new technologies on work is conceptually and methodologically diverse and empirical evidence is not available in a systematic manner: The relationship between technological developments and work has long been a subject of interest across disciplines. Economists have analysed how technologies reshape the structure of tasks and the demand for cognitive and manual skills (e.g., Autor et al., 2003), while organisational psychologists have investigated how digitalisation influences core work characteristics such as autonomy, feedback, or task identity, often drawing on established models of job design (e.g., Hackman & Oldham, 1975). Sociological perspectives, in turn, have highlighted broader questions of control, alienation, and the erosion or enhancement of meaningfulness in technologically mediated work (e.g., Blauner, 1967).

However, despite a rich and varied body of research, empirical findings remain methodologically scattered and conceptually fragmented. Many studies investigate the implications of specific technologies (e.g., robotics, AI, or communication platforms) within isolated occupational contexts, often focusing on a narrow range of outcomes (Carden et al., 2019). Others rely on theoretical or normative analyses about how technology ought to affect work, rather than providing detailed empirical evidence on what actually changes (Koh et al., 2019). As a result, the field lacks an integrative, evidence-based understanding of how work characteristics are being reshaped in practice across different sectors and technological contexts.

This absence of a systematic empirical overview presents a challenge. Without a consolidated knowledge base on how new technologies affect work characteristics, such as

autonomy, complexity, task variety, or social interaction, it remains difficult to understand when and why employees engage in professional development. If we are to foster adaptive learning processes in times of digital transformation, it is essential to first clarify the nature of the work-related changes that employees are reacting to. Addressing this gap requires a systematic synthesis of existing empirical studies that explicitly examine changes in work characteristics due to new technologies.

Professional development has not yet been explicitly and empirically linked to new technologies and their effects on work in existing research: While professional development is becoming increasingly relevant in light of broad societal and organisational changes, it is surprising that relatively little research has examined how it unfolds in direct response to the transformations induced by new technologies. Despite the growing awareness that learning and adaptation are key to navigating technologically mediated work environments (Donald et al., 2023), the processes by which employees develop their competences in such contexts remain insufficiently explored. In particular, empirical studies have yet to investigate how specific changes in work characteristics, triggered by new technologies, elicit professional development.
Furthermore, although conceptual models such as the one proposed by Simons and Ruijters (2004) offer valuable frameworks by conceptualising elaboration, expansion, and externalisation as three key components, there is limited understanding of how these components manifest in practice. It remains unclear under what conditions, and for whom, each aspect becomes particularly salient. Which employees elaborate on their experiences, which are drawn to expansive learning through new information, which actively externalise knowledge through collaborative processes, and how these patterns relate to the specific nature of technological change are questions that existing research has yet to answer.
Taken together, these gaps highlight the need for an integrated, empirically grounded understanding of how employees engage in professional development in response to changes in work due to new technologies. Existing research has not yet captured the full complexity of this phenomenon, either in terms of the actual changes in work characteristics, or the dynamic professional development through which employees adapt. This thesis addresses these issues by posing and answering the following overarching research question:

How do employees engage in professional development in response to new technologies and the related changes in work characteristics?

By answering this research question, the relationship between professional development and changes at work can be understood in more detail, and implications for both practice and research can be derived. Practical implications will address how organisations can support professional development and how both individual and organisational benefits can be fostered to address the challenges of large-scale societal changes such as new technologies. Furthermore, implications for future research directions in professional development will be identified.

2 Theoretical background

2.1 Conceptualising professional development and new technologies

Professional development as a framework for learning at work

Simons and Ruijters (2004) define learning as "implicit or explicit mental and / or overt activities and processes leading to changes in knowledge, skills, attitudes or the ability to learn of individuals, groups or organisations." (p. 211). The changes that can also reshape work processes and outcomes under certain conditions and on different levels. Their definition of learning foregrounds two ideas that repeat through three publications that revolve around professional development at large (Simons & Ruijters, 2001, 2004, 2014): First, much learning is tacit and unfolds as an unplanned by-product of everyday activity; second, learning operates at multiple levels, from the individual to the organisation, and may remain invisible until shifts in behaviour or results make it noticeable (Simons & Ruijters, 2014). This idea of learning is in line with the notion of informal learning by being grounded in action and without a formal structure other than the work that necessitates the learning (e.g., Billett, 2012; Marsick & Watkins, 1999). The literature on informal learning posits some characteristics of learning activities – that is the actual actions that lead to learning – such as the already mentioned observability (mental vs. overt), its intention (deliberate vs. incidental vs. reactive) or whether it is individual or social as an activity itself or as the context of the activity (cf. Mulder, 2013). Learning activities that refer to the above-mentioned definition of learning may vary on all these dimensions.

Being grounded in activities, the authors finally define professional development as an ongoing process of developing one's own competences at and through work (Simons & Ruijters, 2004), where competences refer to the knowledge, skills, and attitudes that are needed in order to accomplish one´s work effectively (Ellström, 1997). Professional development is therefore nothing that is to be achieved ultimately but rather something that is done without a means to an end, as long as someone is professionally engaged. In the 2001 article, Simons and Ruijters describe the so-called "learning professional" as someone who continually aligns vision, methodology and tools with a changing knowledge base, moving fluidly between practice, research and contribution to the wider community.

The mechanism of becoming such a learning professional is by engaging in three different but complementary aspects of professional development that subsume learning activities independent of the already mentioned characteristics of learning activities: *elaboration, expansion* and *externalisation*. First sketched in 2001 and elaborated most fully in the 2004 article, *elaboration* is reflective learning rooted in experience. It surfaces and reorganises tacit knowledge (Eraut, 2000) so that implicit routines become consciously adjustable. The authors link elaboration to practices such as reflection-in-action versus reflection-on-action (after Schön, 1987) and highlight the importance of aspects such as variation, responsibility, feedback, or reflection in the work setting to trigger that reflective stance. By engaging in elaboration, professionals gain the confidence to cope with everyday disturbances.

Expansion addresses situations where tacit adjustment is insufficient. Here the learner engages in explicit inquiry to acquire new concepts or test action theories. Simons and Ruijters (2014) distinguish three routes: theoretical, inquiry and critical learning. Expansion therefore fits onto learning theories that stress deliberate knowledge construction, problem formulation and hypothesis testing, and the authors argue that it becomes indispensable whenever tasks change, risks increase, or fundamental assumptions need to be questioned (Simons & Ruijters, 2004). *Externalisation* converts personal insight into public by engaging in knowledge production by means such as articles, tools, workshops or organisational policies, so that learning circulates beyond the individual and fuels collective competence. Externalisation is both the culmination of earlier learning efforts and a fresh stimulus, because visibly committing to milestones helps people to also commit to their own professional development (e.g., Simons & Ruijters, 2004; 2014).

Across all three publications, learning is portrayed as a continuum from silent adaptation to overt knowledge creation, with professional development emerging from the dynamic interplay of elaboration, expansion and externalisation. Each aspect draws on distinct learning theories, such as experiential learning (e.g., Kolb, 1984) or inquiry-based knowledge building (e.g., Hakkarainen et al., 2000) and knowledge-sharing models (e.g., Nonaka et al., 1998), yet together they provide a framework for understanding how workers maintain competence in changing contexts – as for instance the rapid diffusion of new technologies at the workplace that are said to redefine how tasks are organised and executed in its core.

Defining technology

The concept of "technology" is notoriously difficult to pin down. Despite its ubiquity across organisational research, psychology, sociology, education, and management studies, few fields offer a consistent or content-based definition (McOmber, 1999). A key reason is the layered and nested nature of technology: a single artefact such as an intelligent robot integrates software and hardware, sensors and algorithms, embedded within industrial processes and implementation strategies. This multiplicity makes technology an "equivoque", as Weick (1990) put it. Existing research on the effects of technology, often emerging from organisational theory, tends to be highly detailed, situated, and context specific. This is largely due to the interpretivist view of technology as something deeply embedded within, and co-constructed by, its social context (cf. Liker et al., 1999). While this perspective provides valuable depth, it also makes it difficult to delineate technology as a discrete analytical construct. Much like Heidegger's conception of technology as a fundamental human event (Heidegger, 1977), this view complicates the task of defining, operationalising, and empirically investigating that which is a "technology". McOmber (1999) warned against assuming a clear understanding of technology and instead distinguished three dominant perspectives: technology-as-instrumentality (as a functional tool), technology-as-industrialisation (as historically contingent mass production), and technology-as-novelty (as futuristic disruption). While these perspectives often co-exist in research from different disciplines and backgrounds, most empirical research implicitly adopts an instrumental view, examining specific tools, such as AI systems, software

platforms, or communication media, in terms of their function or design. Building upon that, this thesis developed a pragmatic definition of technology that is grounded in its functional role within the workplace, specifically and critically in terms of the work tasks they were designed for. Based on the aptly named task-based approach of David H. Autor (Autor et al., 2003; Autor, 2013; Autor 2015) and the analyses of McOmber (1999), we define technologies as mechanical or digital tools or systems that complement or replace the accomplishment of work tasks, a task being "a unit of work activity that produces output." (Autor, 2013, p. 4). In line with this definition, three analytically distinct types were conceptualised in previous research: *Task-supporting technologies* are technologies that employees use directly to carry out a task while retaining full agency, for example spreadsheet applications or decision-support software (Mulder et al., 2022). *Task-replacing technologies* automate part or all of a work process once they have been activated, drawing on techniques such as robotic process automation or machine learning to perform operations with minimal further human involvement. *Communication technologies* link human actors by enabling the exchange of information and coordination through channels such as videoconferencing, instant messaging or shared project platforms (Mulder et al., 2022). These categories allow a fine-grained examination of how different functional logics affect the process of task completion and therefore work itself.

Having defined professional development and outlined the various types of new technologies, now the questions need to be answered in how these technologies and learning activities are related.

2.2 Changes at work due to new technologies

Technologies, particularly since the era of industrialisation, have long been recognised as drivers of change for work and jobs (Schwab, 2017; Brynjolfsson & McAfee, 2014). To analyse these effects, various work design models that systematically categorise work characteristics offer valuable frameworks.

A prominent example is the Job Characteristics Model (JCM) introduced by Hackman and Oldham (1975) that proposes five core "motivational" features (i.e., skill variety, task identity, task significance, autonomy and feedback) whose presence is assumed to enhance experienced meaningfulness, responsibility, and knowledge. Meta-analytic reviews confirm positive average effects, yet also highlight boundary conditions and conceptual gaps: the model omits social and contextual factors, treating the motivational features as uniformly desirable aspects (cf. Fried & Ferris, 1987). Simultaneously to the JCM, Karasek (1979) developed the more nuanced idea of job demands (e.g., workload) that are contrary to the job control experienced by the individual, a dynamic which, if not balanced, causes stress and strain. This main idea of some form of valence regarding characteristics persisted and was ultimately shown to be the core of the Job Demands–Resources model (JD-R) (Demerouti et al., 2001), that further expands on different job demands (e.g., time pressure, that if mismanaged leads to exhaustion), and job resources (e.g., feedback, that if mismanaged leads to disengagement). Being conceptually more nuanced than Karasek´s

(1979) idea, both of these models are within a tradition of very fine-grained definitions of specific work characteristics as either demanding or engaging and its balance contributing to employee wellbeing. While this dualism captures dynamics, it inherits a normative tension: whether a particular attribute is coded as a resource or a demand depends on prior value judgements, leaving limited room for ambiguity, contextual moderators, individual differences, or paradox effects. Lastly, integrative frameworks seek to overcome some of these limitations by categorising a wider set of characteristics often for descriptive purposes without attaching valence a priori. An early attempt was the Work Design Questionnaire (WDQ) by Morgeson and Humphrey (2006) that for instance subsumes a plethora of work characteristics under four categories (i.e., task, social, knowledge, and contextual characteristics), encouraging researchers and practitioners to examine the overarching configuration rather than isolated single predictors. In line with this approach and building on it, a lot of heavy lifting has been done by Sharon Parker in recent years, with the SMART model of work design being one of the latest developments in her research (Parker & Knight, 2024). Within this model, the authors theoretically grouped a plethora of first-order characteristics into five higher-order factors (i.e., stimulating, mastery, autonomous, relational and tolerable work characteristics), and were able to demonstrate that a multidimensional structure predicts overall job satisfaction by means of managing motivation, strain, learning, and social aspects (Parker & Knight, 2024).

While these models on work design offer valuable insights into the range of characteristics that work can consist of – and even capture the dynamics between these characteristics – none of the models explicitly links to new technologies. Some theoretical and empirical work revolves around Cherns's socio-technical systems theory (Cherns, 1986; Appelbaum, 1997) and Barley's (1990) alignment perspective, both rooted in early contingency thinking in the tradition of Burns and Stalker (1994), and Orlikowski's (2007) notion of sociomateriality. While their body of work was seminal in showing that organisational structure, social factors, and technologies at work are inseparable, they all rest on a constructivist notion in which technologies are shaped, interpreted and continually re-configured through social negotiation, and the social context is, in turn, profoundly shaped by those technologies. Such a view is incompatible with the prevalent conceptualisation of new technologies as concrete entities that transform work itself rather than the negotiated meanings around it. Consequently, these rich theoretical lenses are most useful when one adopts an interpretivist stance on technology outlined by Liker et al. (1999), but not with the instrumental perspective that the present conceptualisation of technologies is based on. In addition to the scarcity of models that clearly conceptualise and explain the effects of technologies on work at an instrumental level, ideas on how to analyse what these changes mean for professional development are equally nascent. Harteis et al. (2020), acknowledging this gap, issued a plea for future studies to examine different technologies more closely across various domains and to incorporate new ways of thinking about workplace learning and professional development by for instance applying the concept of conceptual change. Some studies offer initial evidence. For instance, Goller et al. (2021) investigated qualitatively how changes due to automation technologies were experienced by dairy farmers finding a strong shift in work

tasks towards data monitoring and control rather than physical labour due to technologies automating routine tasks. This digital shift required the dairy farmers to combine traditional agricultural knowledge with digital literacy, and an understanding of the physical and digital elements of the workplace. Similar results were found by sociological research that touches on aspects of workplace learning when studying new digital arrangements, although primarily being concerned with digitisation from a political and economic perspective (Pfeiffer, 2021). Specifically, Pfeiffer (2016) found in a qualitative analysis of assembly line work that in non-routine tasks that are not being replaced by automation technologies, aspects of individual experiential learning as well as collective learning become important. This learning is for instance crucial for understanding the new functions of technology, performing troubleshooting, and adapting to changing workflows.

These initial studies nicely illustrate, that technologies, mostly through the automation of monotonous or physical tasks, can transform the experience of work and, even more importantly, can be linked to workplace learning. However, what these studies do not provide is (a) a systematic model to examine different effects on work, such as by referencing established models of work characteristics, and (b) to analyse how various technologies, beyond automation technologies, might play distinct roles and differ from one another. Additionally, it remains unclear whether workplace learning merely involves acquiring knowledge for using technologies and troubleshooting, or if both the effects on work and the learning processes are potentially much broader. For these analyses, a perspective is needed that allows for a broad incorporation of various models of work characteristics while simultaneously establishing a clear link to learning and development.

2.3 Equilibration through professional development

According to Dewey (1910), a “perplexity”, “obstacle” or “problem” (Mischel, 1971, p. 343) provides the impetus for learning through what is called a cognitive conflict in the theory on cognitive development by Jean Piaget. Essential to Piaget´s idea of learning is the notion, that an “external intrusion” (Piaget, 1967), that is, the perception of something that does not fit into the existing understanding of the world (represented in a system of cognitive schemas), triggers a cognitive conflict (“disequilibrium”). Learning thus means resolving this cognitive conflict, by reestablishing cognitive consistency (“equilibrium”) through engaging in a cognitive process called “equilibration”, which includes the non-contradictory assimilation of new information into existing cognitive structures (“assimilation”) or adjusting these structures in a way so that the novel information that introduced the cognitive conflict is no longer disturbing (“accommodation”) (cf. Piaget, 1952; Bourgeois, 2012; Mischel, 1971). This perspective on learning offers a cognitive foundation for the view proposed by Simons and Ruijters (2004). According to this view, professional development leads to "equilibration" through engagement in learning activities reflecting elaboration, expansion, and externalisation, which may vary depending on what is perceived in the external world and what causes cognitive conflict.

On the one hand, the new technologies themselves can trigger cognitive conflict. When a task-supporting technology enhances an activity that was previously done manually with digital elements, the employee can compare the two experiences and draw on past experience to refine existing routines (i.e., elaboration). When a task-replacing technology automates parts of a process to task completion, the employee may find themselves having to acquire new conceptual and procedural knowledge about both the new workflow as well as the technology that is responsible for it (i.e., expansion). When a communication technology enables communication in both frequency and quality, employees may be more inclined to articulate their knowledge and engage in collaborative problem solving due to the availability of others at the push of a button.

On the other hand, the changes in work characteristics that the new technologies lead to may serve as "external intrusions" (Piaget, 1967). Formally, change can be defined as the variation of one property of an otherwise stable entity at different points in time between which one or more transformative events occurred or logically had to occur (e.g., Russell, 1937). If the introduction of a new technology is viewed as a transformative event, then it leads to variation of certain properties of work above and beyond the novelty and intrusiveness that the technologies themselves represent. Recent research, inspired by the variance approach of Van de Ven and Poole (2005), has conceptualised the dimensions of changes in work characteristics both in terms of their direction (increase or decrease) and intensity (level of strength) (Mulder et al., in progress). This differentiation provides additional insight for understanding whether employees may engage in elaboration, expansion, or externalisation when reacting to perceived changes. For instance, gradual or incremental (low-intensity) changes in work characteristics are more likely to be assimilated into existing cognitive structures without requiring substantial restructuring. Such minor changes may thus predominantly stimulate elaboration, characterised by incremental refinement and reinforcement of existing knowledge and routines (Van Woerkom & Croon, 2008). Conversely, abrupt (high-intensity) changes represent more fundamental disturbances to established cognitive structures, necessitating significant cognitive accommodation. This accommodation may typically manifest as expansion, as employees must acquire new conceptual or procedural knowledge to restore equilibrium (cf. Illeris, 2003). Regarding the direction of change, resource-based theoretical frameworks, such as the previously mentioned Job Demands-Resources (JD-R) model and the underlying conservation of Resources (COR) theory, suggest important implications. An increase in demanding work characteristics (e.g., workload or task complexity), typically consumes substantial cognitive, emotional, and psychological resources, thereby intensifying cognitive conflicts. Such increases might increase the likelihood of learning activities that foster accommodation (e.g., expansion as previously argued), as employees must invest considerable effort to restructure their cognitive schemas (Hobfoll, 1989; Hobfoll et al., 2018). Conversely, a decrease in demanding characteristics may enable employees to conserve and reinvest cognitive resources, facilitating smoother assimilation and thus promoting elaboration, since fewer adjustments are needed for existing schemas. Consequently, both the direction and intensity of changes in work characteristics are central to determining the type of cognitive processing

employees engage in, thereby influencing whether elaboration, expansion, or externalisation occurs.

However, two important limitations need to be recognised. Firstly, the specific impacts of changes in work characteristics may vary considerably depending on their relevance within a given professional or organisational context. The professional significance of certain characteristics (and whether they change in what intensity and direction) may amplify or diminish the perceived cognitive conflict and the consequent professional development. For instance, in some professions, strong fluctuations in workload may be considered to be normal, therefore not leading to any cognitive conflicts (e.g. emergency paramedics), while for others, for instance sudden spikes in workload mean extreme disturbances (e.g., project managers). Secondly, the interaction between new technologies and affected work characteristics must also be considered. For example, a task-replacing technology could sharply increase task complexity, initially requiring expansion through significant cognitive accommodation, while simultaneously decreasing physical workload, thereby facilitating cognitive assimilation and elaboration. Such multidimensional changes highlight the necessity of examining the interplay between technology-induced and work characteristic-driven changes. Finally, this dynamic must also be considered when examining the benefits and outcomes of professional development in this context.

2.4 Work outcomes, individual characteristics, and professional development

Equilibration processes not only serve to restore cognitive equilibrium but also form the foundation for competence development as a central outcome of professional development. As Piaget (1952) suggested, repeated engagement in cognitive processes fosters the progressive refinement and restructuring of cognitive schemas. Through these equilibration cycles, individuals develop increasingly complex and integrated cognitive structures that embody competences, comprising procedural skills, conceptual knowledge, and social capabilities (cf. Simons & Ruijters, 2004; Tynjälä, 2008; Ellström, 1997). These competences, constructed through the assimilation and accommodation of novel experiences, enhance the ability to perform tasks, solve problems, and respond flexibly to new or evolving demands. Thus, equilibration not only resolves immediate cognitive conflicts but also systematically builds durable, transferable competences applicable across a range of work contexts, enabling employees to adapt and respond effectively to subsequent changes. Applying these refined competences may contribute significantly to several critical individual and organisational outcomes, such as emotional exhaustion, job satisfaction, and organisational commitment. Emotional exhaustion is defined as a feeling of being emotionally overwhelmed and exhausted by work and occurs when a person's emotional resources are depleted (Maslach et al., 1997). Professional development may, through the productive processing of changes at work, help develop competences to alleviate related anxieties, thereby reducing emotional exhaustion in times of change due to new technologies. Job satisfaction, i.e., the satisfaction an individual perceives regarding certain

aspects of their job (Pejtersen et al., 2010) is a sign of increased engagement in professional development that may imply a certain autonomy to pursue such activities, but more importantly, it enhances the experience of competence, fostering a sense of self-determination (e.g., Ryan & Deci, 2020).
Finally, emerging evidence of a positive association for organisational commitment with workplace learning has been found (e.g., Lee et al., 2019; Wulan et al., 2024). Organisational commitment is defined as an attitude that characterises the employee's relationship with the organisation and influences their decision to maintain membership within it (Allen & Meyer, 1996). The rationale here is that engaging in professional development as extra-role behaviour involves the investment of resources beyond what is formally required by the employer. Employees who expend these additional efforts may develop a stronger connection to their work and organisation. While the "career development" concept from the study by Wulan et al. (2024) might be most closely related to externalisation only, it nevertheless provides an intriguing empirical basis to explore the relationships between professional development and organisational commitment in greater depth.

When considering individual-level factors that may moderate an individual's inclination to engage in professional development, two personal characteristics stand out as particularly relevant: occupational self-efficacy and technological acceptance. Occupational self-efficacy, grounded in Bandura's social cognitive theory (Bandura, 1977) and focused on the work domain, is defined as the feeling of competence regarding one's own capability to accomplish work tasks (Rigotti et al., 2008). Within this framework, occupational self-efficacy is best understood as a potential moderator of the relationship between changes at work and engagement in professional development. Individuals with higher self-efficacy are likely better equipped to cope with and respond productively to workplace changes, making them more inclined to engage in learning activities when confronted with changing work characteristics. While increased self-efficacy can be an outcome of informal learning (e.g., Kromah et al., 2024; Yoon et al., 2018), in the present model, its primary role is to potentially strengthen or weaken the link between changes at work and professional development.
Similarly, technological acceptance may serve as an important moderator in the relationship between new technologies and professional development. Technological acceptance is broadly defined as the individual's reaction to using, intention to use, and actual use of (information) technology (Venkatesh et al., 2003). Employees with high technological acceptance are more likely to actively seek out professional development opportunities related to new technologies, whereas low acceptance may hinder such engagement. While it has been proposed that professional development in the context of new technologies could also enhance technological acceptance, the primary focus here is on how varying levels of acceptance influence the willingness to engage in learning activities in response to technological change. Although some literature explores how informal learning can contribute to the development of technology acceptance (see Straub, 2009 for a detailed analysis), empirical evidence for this pathway remains limited, and it is not the primary assumption in this framework. The UTAUT model by Venkatesh et al. (2003) currently provides the most comprehensive conceptualisation of technological acceptance,

encompassing not only assessments of technological features (such as usefulness and ease of use) but also individual factors (such as anxiety and perceived competence) and contextual influences (including expectations from one's environment and perceptions of leadership).

2.5 Summary and visualisation of the theoretical background

This theoretical framework highlights the dynamic and multifaceted nature of professional development within the context of new technologies and changes in work characteristics. Central to this understanding is the concept of cognitive disequilibrium, in which both the introduction of new technologies and changes in work characteristics serve as "external intrusions" (Piaget, 1967) that disrupt existing cognitive models, triggering individuals to engage in learning activities aimed at restoring equilibrium (i.e., equilibration). The nature of these changes, characterised for instance by what is changing as well as the intensity and direction of the change, determines whether employees engage in elaboration, expansion, or externalisation as modes of professional development. The impact of these changes is context-dependent, varying by profession, organisational setting, and the interplay between types of technologies and the work characteristics they affect. This complexity underscores the necessity of viewing professional development as an ongoing and situated process of equilibration, where cognitive restructuring leads not only to competence development but also to important work outcomes such as job satisfaction, emotional exhaustion, and organisational commitment.

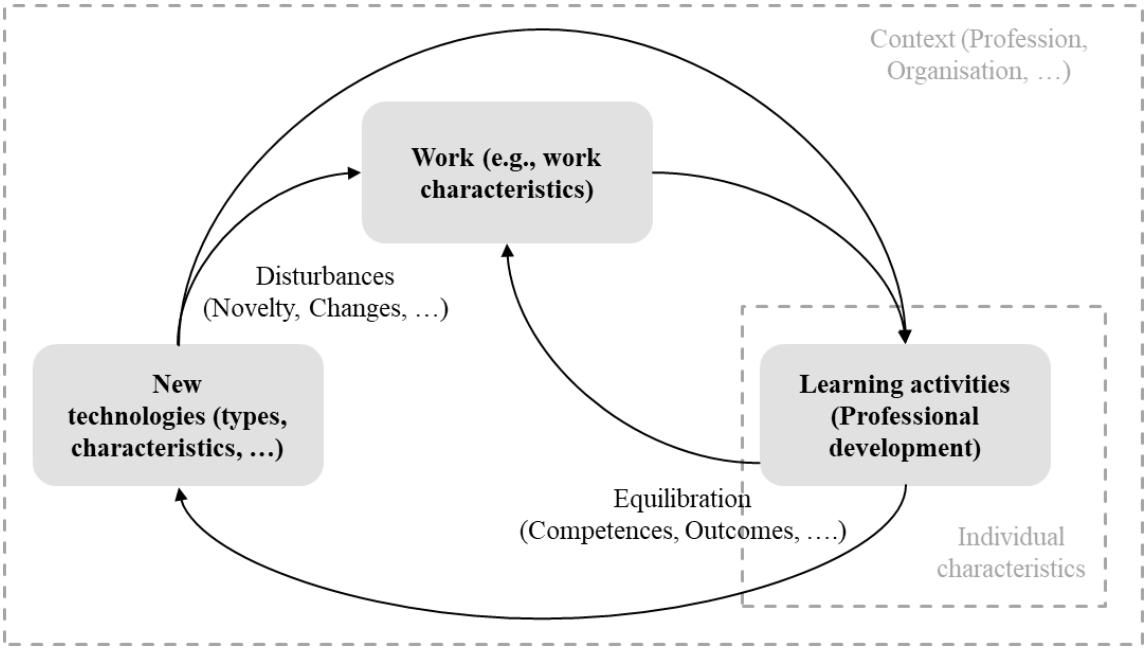

Figure 1. *Theoretical model illustrating effects of new technologies on work and learning activities as a dynamic response. The arrows indicate disturbances originating from the new technologies on the one hand, and equilibration through learning activities as a counterbalance on the other, each illustrating the respective theoretical mechanisms.*

Individual characteristics like occupational self-efficacy and technological acceptance further affect engagement in professional development, shaping how employees respond to evolving work environments.
In sum, this framework shifts the focus from static work design models to a dynamic, process-oriented understanding of how change, both through new technologies themselves but also the related changes in work characteristics, can lead to professional development through equilibration. Figure 1 synthesises these relationships, illustrating how external intrusions provoke cognitive and behavioural responses that ultimately shape individual competences and broader organisational outcomes.

3 Aim of the thesis and overview of the studies

3.1 Aim of the thesis

Based on the overarching research question and the theoretical background, the following aims are pursued:

Aim 1 – Establishing the relationships between new technologies and professional development.
The first aim addresses the unexplored intersection of new technologies and professional development, focusing explicitly on the fundamental question of whether, and how, new technologies at work prompt professionals to engage in professional development. While existing research acknowledges separately the impact of technological developments on work and the importance of professional development, empirical evidence explicitly linking the two remains scarce. Through qualitative interviews in Study 2, the thesis provides initial empirical illustrations of how different types of new technologies (i.e., task-supporting, task-replacing, and communication technologies) directly prompt employees to engage in different aspects of professional development (i.e., elaboration, expansion, externalisation) and explores the meaning of these relationships. Subsequently, the results of the quantitative survey conducted in Study 3 further consolidate the relationships by examining whether employees' engagement in elaboration, expansion, and externalisation varies according to the types of new technologies used.

Aim 2 – Identifying how new technologies change work characteristics and how these changes relate to professional development, including its predictors and outcomes.
The second aim is to explicitly investigate how new technologies change work characteristics and how these changes trigger employees to engage in professional development, as existing models on work characteristics neither address the impact of new technologies nor are primarily concerned with professional development.
To address this gap, a systematic review of the available evidence was conducted in Study 1, showing how different technologies affect work characteristics across various professions

and what gaps remain. Qualitative interview data from Study 2, henceforth focusing on the financial sector, expanded upon the work characteristics identified in the systematic review by revealing additional profession-specific work characteristics and ultimately linking them to aspects of professional development (i.e., elaboration, expansion, and externalisation). Building upon the findings from Studies 1 and 2, quantitative survey data from Study 3 tested established relationships. Additionally, the relationships between professional development and individual-level characteristics (e.g., self-efficacy, technological acceptance) and work outcomes (e.g., organisational commitment, job satisfaction, emotional exhaustion) were tested in Study 3.

Aim 3 – Critically appraising conceptualisations of new technologies, changes in work characteristics and professional development as well as the approaches for investigating them.

Drawing from the choices made in Studies 1 and 2, the third aim of this thesis is to critically evaluate existing conceptualisations, theoretical frameworks and methodological approaches employed across the research.

From the definition of new technologies necessary for conducting Study 1 to the conceptualisation and measurement of professional development necessary for Studies 2 and 3, many decisions were exploratory and brought together in this context for the first time. Studies 2 and 3 showed that existing models on work design offer different systems and categories of work characteristics but neither account for new technologies nor explicitly address professional development, workplace learning, or similar conceptualisations. In addition, this thesis reflects on how professional development is conceptualised in comparison to other models of workplace learning, examines its empirical and conceptual structure in relation to the investigated constructs, and considers how it manifested in the present studies. Ultimately, by drawing from the conceptual gaps and methodological challenges encountered, this thesis aims to inform future research that further integrates technological development, changing work characteristics, and professional development as interrelated phenomena in contemporary workplaces.

3.2 Overview of the studies

To achieve the outlined objectives, three consecutive and interconnected studies were conducted as previously mentioned. These studies have either been published in peer-reviewed journals, are submitted, or are in preparation to be submitted:

Study 1 – The effects of technological developments on work and their implications for continuous vocational education and training: A systematic review.

This study – reported in Chapter 4 of this thesis – addressed the second research aim by means of a systematic literature review. The study investigated broadly how new technologies affect work characteristics. The guiding research question was: What are the effects of technological developments on work characteristics? A total of N = 28 empirical

studies were included and analysed through narrative synthesis (Rodgers et al., 2009). The review identified not only categories of work characteristics affected by different technologies, but also the specific ways in which these technologies changed them, which fundamentally informed the selection of variables and methodological approach in Studies 2 and 3.

Study 2 – The meaning of the relationships between new technologies, changes in work characteristics and professional development in the financial sector.

This study – reported in Chapter 5 of this thesis – addressed the first and second research aims by means of an exploratory qualitative interview study using the Critical Incident Technique (CIT; Flanagan, 1954). The study investigated how finance professionals engage in professional development in response to new technologies and related changes in work. The research question guiding this study was: How does professional development emerge from using new technologies and the associated changes in work characteristics?

N = 8 finance professionals were interviewed. The results obtained from the content analysis (Schreier, 2014) illustrated relationships between different types of new technologies and the aspects of professional development and additionally revealed more profession-specific work characteristics, which all together informed the development of Study 3.

Study 3 – The relationships between professional development, new technologies and changes in work characteristics: a survey study in finance.

This study – reported in Chapter 6 of this thesis – addressed the first and second aims of this thesis by means of a cross-sectional quantitative survey study in the financial sector investigating the relationships identified in Study 2. The guiding research question was: What are the relationships between different types of new technologies, changes in work characteristics, and forms of professional development?

N = 95 finance professionals participated in the study. Analyses of variance and correlation analyses (Field, 2024) uncovered relationships between some of the core constructs. Building upon Studies 1 and 2, the results of this study highlighted the boundaries of current knowledge, thereby enabling a discussion of the most promising next steps, both conceptually and methodologically, for a future research agenda. In so doing, the completion of this study, which built upon the findings of Studies 1 and 2, made it possible to fully address the third and final aim of the thesis by enabling discussion and recommendations for a future research agenda grounded in its overall conclusions.

Figure 2 visualises this research agenda. In the following chapters, the described studies are presented in detail and chronological order according to the aims of this thesis.

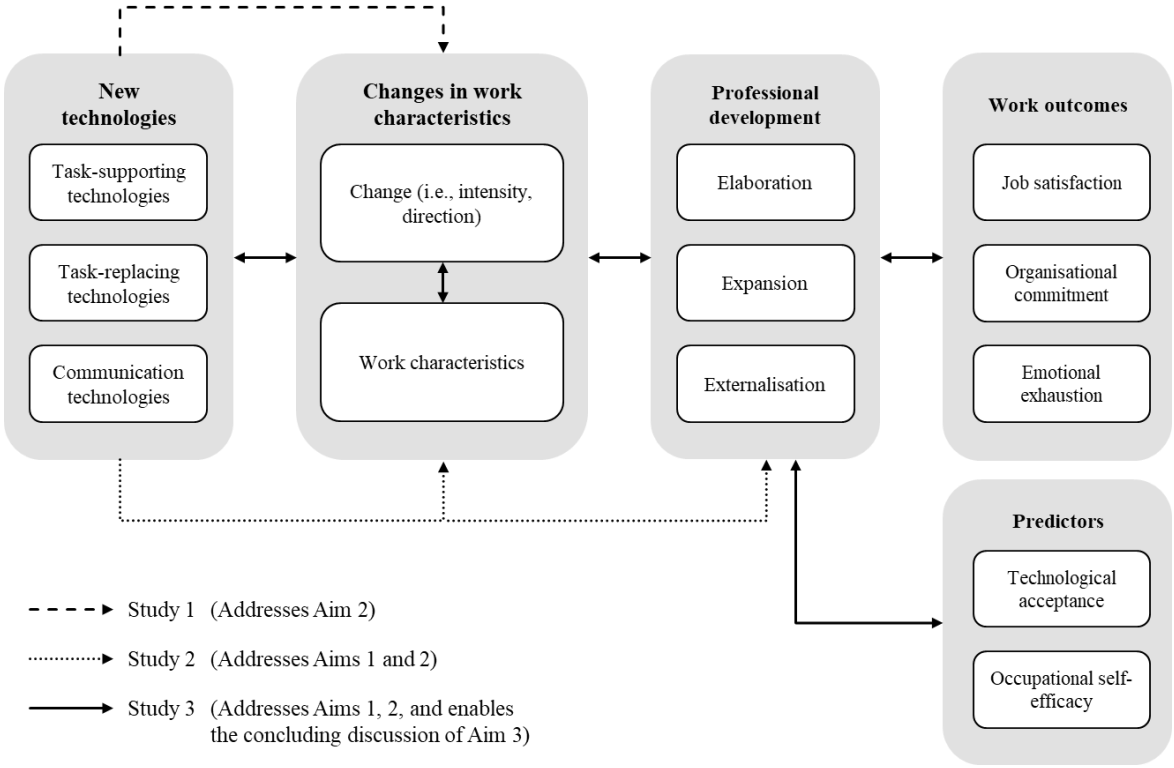

Figure 2. *Visualisation of the research model*

4 Study 1: The effects of technological developments on work and their implications for continuous vocational education and training: a systematic review[1]

Abstract

Technology is changing the way organizations and their employees need to accomplish their work. Empirical evidence on this topic is scarce. The aim of this study is to provide an overview of the effects of technological developments on work characteristics and to derive the implications for work demands and continuous vocational education and training (CVET). The following research questions are answered: What are the effects of new technologies on work characteristics? What are the implications thereof for continuous vocational education and training? Technologies, defined as digital, electrical or mechanical tools that affect the accomplishment of work tasks, are considered in various disciplines, such as sociology or psychology. A theoretical framework based on theories from these disciplines (e.g. upskilling, task-based approach) was developed and statements on the relationships between technology and work characteristics, such as complexity, autonomy, or meaningfulness, were derived. A systematic literature review was conducted by searching databases from the fields of psychology, sociology, economics and educational science. 21 studies met the inclusion criteria. Empirical evidence was extracted and its implications for work demands and CVET were derived by using a model that illustrates the components of learning environments. Evidence indicates an increase in complexity and mental work, especially while working with automated systems and robots. Manual work is reported to decrease on many occasions. Workload and workflow interruptions increase simultaneously with autonomy, especially with regard to digital communication devices. Role expectations and opportunities for development depend on how the profession and the technology relate to each other, especially when working with automated systems. The implications for the work demands necessary to deal with changes in work characteristics include knowledge about technology, openness towards change and technology, skills for self- and time management and for further professional and career development. Implications for the design of formal learning environments (i.e. the content, method, assessment, and guidance) include that the work demands mentioned must be part of the content of the trainings, the teachers/trainers must be equipped to promote those work demands, and that instruction models used for the learning environments must be flexible in their application.

4.1 Introduction

In the face of technology-driven disruptive changes in societal and organisational practices, continuous vocational education and training (CVET) lacks information on how the impact

[1] This chapter was published in advance: Beer, P., & Mulder, R. H. (2020). The Effects of Technological Developments on Work and Their Implications for Continuous Vocational Education and Training: A Systematic Review. *Frontiers in Psychology, 11*, Article 918. https://doi.org/10.3389/fpsyg.2020.00918

of technologies on work must be considered from an educational perspective (Cascio and Montealegre, 2016). Research on workplace technologies, i.e. tools or systems that have the potential to replace or supplement work tasks, typically are concerned with one out of two areas of interest: First, economic and sociological research repeatedly raises the question on technological mass-unemployment and societal inequality as a result of technological advances (Frey and Osborne, 2017; Brynjolfsson and McAfee, 2014; Ford, 2015). And second, management literature questions the suitability of prevailing organizational structures in the face of the so-called "fourth industrial revolution" (Schwab, 2017), taking visionary leaps into a fully automated future of digital value creation (Roblek et al., 2016). Many of the contributions of scholars discuss the enormous potential of new technologies for work and society at a hypothetical level, which led to a large number of position papers. Moreover, the question on what consequences recent developments, such as working with robots, automated systems or artificial intelligence will have for different professions remain largely unclear. By examining what workplace technologies actually "do" in the work environment, it was suggested that work tasks change because of technological developments (Autor et al., 2003; Autor, 2015). This is due to technologies substituting different operations or entire tasks and thus leave room for other activities. Jobs are defined by the work tasks and the conditions under which the tasks have to be performed. This in turn defines the necessary competences, that is the potential capacity to carry out a job (e.g. Ellström, 1997). Therefore, CVET needs to be informed on the changes that technology causes in work tasks and the consequential characteristics of work. Only then CVET is able to derive the required competences of employees and organise learning environments that foster the acquirement of these competences. These insights can be used to determine the implications thereof for the components of formal learning environments: content, didactics, trainer behaviour, assessment, and resources (e.g. Mulder et al., 2015).

The aim of this systematic literature review is to get insight into the effects of new technological developments on work characteristics in order to derive the necessary work demands and their implications for the design of formal learning environments in CVET. Therefore, the following research questions will be answered:

1. What are the effects of new technologies on work characteristics?
2. What are the implications thereof for continuous vocational education and training?

Theoretical considerations on the relationships between technology and work characteristics are presented before the methods for searching, selecting and analysing suitable studies are described. Regarding the results section, the structure is based on the three main steps of analysing the included studies: First, the variables identified within the selected studies are clustered and defined in terms of work characteristics. Second, a comprehensive overview of evidence on the relationships between technologies and work characteristics is displayed. Third, the evidence is evaluated regarding the work demands that result from technologies

changing work characteristics. Finally, the implications for CVET and future research as well as the limitations of this study will be discussed.

4.2 Theoretical framework

In this section, a conceptualization of technology and theoretical assumptions on relationships between technology and work characteristics will be outlined. Research within various disciplines, such as sociology, management, economics, educational science, and psychology was considered to inform us on the role of technology within work. Completing this section, an overview of the various components of learning environments is provided to be used as a basis for the analyses of the empirical evidence.

Outlining technology and recent technological developments

A clear definition of technology often lacks in studies, what may be due to the fact that the word itself is an "equivoque" (Weick, 1990, p.1) and a "repository of overlapping inconsistent meanings" (McOmber, 1999, 149). A suitable definition can be provided by analysing what technologies actually "do" (Autor et al., 2003, p.1280). The primary goal of technology at work is to save or enhance labour in the form of work tasks, defined as "a unit of work activity that produces output" (Autor, 2013, p.186). Technology can therefore be defined as mechanical or digital devices, tools or systems. These are used to replace work tasks or complement the execution of work tasks (e.g. McOmber, 1999; Autor et al., 2003). According to this view, technology is conceptualised according to "its status as a tool." ("instrumentality"; McOmber, 1999, p.141). Alternatively, technology is understood as "the product of a specific historical time and place", reflecting a stage of development within a predefined historical process ("industrialization"; McOmber, 1999, p.143) or as the "newest or latest instrumental products of human imagination" ("novelty"; McOmber, 1999, p.143), reflecting its nature that is rapidly replacing and "outdating" its predecessors. The definition according to "instrumentality" is particularly suitable for this research, as the interest focuses on individual-level effects of technologies and its use for accomplishing work. Therefore, the technology needs to be mentioned explicitly (e.g. "robot" instead of "digital transformation") and described specifically in the form with which the employee is confronted at the workplace.

Different definitions may reflect different perspectives on the role of technology for society and work. These perspectives in the form of paradigmatic views (Liker et al., 1999) include philosophical and cultural beliefs as well as ideas on organisational design and labour relations. They differ with regard to the complexity in which the social context is believed to determine the impact of technology on society. Listed in accordance to increasing social complexity, the impact may be determined by technology itself (i.e. "technological determinism"), established power relations (i.e. "political interest"), managerial decisions (i.e. "management of technology"), or the interaction between technology and its social context (i.e. "interpretivist") (Liker et al., 1999). Later research added an even more complex

perspective, according to which the effects of technology on society and organisations are determined by the relations between the actors themselves (i.e. "sociomateriality"; Orlikowski and Scott, 2008). Paradigmatic views may guide research in terms of content, purpose and goals, which in turn is likely to affect the methods and approach to research and may be specific to disciplines. For instance, Marxist sociological research following the view of "political interest" or research in information systems following the view of "management of technology".

New technological developments are widely discussed in various disciplines. For instance, Ghobakhloo (2018) summarises the expected areas of application of various technological concepts within the "smart factory" in the manufacturing industry: The internet of things as an umbrella term for independent communication of physical objects, big data as procedure to analyse enormous amounts of data to predict the consequences of operative, administrative and strategic actions, blockchain as the basis for independent, transparent, secure and trustworthy transaction executed by humans or machines, and cloud computing as an internet-based flexible infrastructure to manage all these processes simultaneously (Ghobakhloo, 2018; Cascio and Montealegre, 2016).

The central question to guide the next section is to what extent these new technologies, and also well-established technologies such as information and communication technologies (ICT), which are constantly being expanded with new functions, could influence work characteristics on a theoretical basis.

Theories on the relationships between technology and work characteristics.

A central discussion on technology can be found in the sociological literature on deskilling versus upgrading (Heisig, 2009). The definition of "skill" in empirical studies on this subject varies regarding its content by describing either the level of complexity that an employee is faced with at work, or the level of autonomy that employees are able to make use of (Spenner, 1990). Theories advocating the deskilling of work (e.g. labour process theory; Braverman, 1998) propose that technology is used to undermine workers´ skill, sense of control, and freedom. Employees need to support a mechanized workflow under constant surveillance in order to maximize production efficiency (Braverman, 1998). Other authors, advocating "upskilling" (Bell, 1976; Zuboff, 1988; Blauner, 1964), propose the opposite by claiming that technology frees employee´s from strenuous tasks, leaving them with more challenging and fulfilling tasks (Francis, 1986). In addition, issues of identity at work were raised by Blauner (1964) who acknowledged that employees may feel "alienated" as soon as technologies change or substitute work that is meaningful to them, leaving them with a feeling of powerlessness, meaninglessness, or self-estrangement (Shepard, 1977).

In sum, sociological theories suggest that technology has an impact on the level of freedom, power and privacy of employees, determining their identity at work and the level of alienation they experience.

According to contingency theories (Burns and Stalker, 1994; Liker et al., 1999) technology is a means to reduce uncertainty and increase competitiveness for organizations (Parker et al., 2017). Therefore, the effects of technology on the employee depend on strategic decisions that fit the organizational environment best. When operational uncertainty is high,

organizations get more competitive by using technology to enhance the flexibility of employees in order to enable a self-organized adaption to the changing environment (Cherns, 1976). This increases employee's flexibility by allowing them to identify and decide on new ways to add value to the organisation ("organic organisation"; Burns and Stalker, 1994). When operational uncertainty is low, organizations formalize and standardise procedures in order to optimise the workflow and make outputs more calculable ("mechanistic organisation"; Burns and Stalker, 1994). This leads to less opportunities for individual decision-making and less flexibility for the employees.

In sum, contingency theories suggest, that the effects of technology depend on the uncertainty and competitiveness in the external environment and may increase or decrease employee's flexibility and opportunities for decision-making and self-organisation.

Economic research following the task-based approach from Autor et al. (2003) suggests, that technology substitutes routine tasks and complements complex (or "non-routine") ones. Routine manual and cognitive tasks usually follow a defined set of explicit rules, which makes them susceptible to automation. By analysing qualification requirements in relation to employment rates and wage development, it was argued that workplace automation substitutes routine and low-skill tasks and thus favours individuals who can carry out high-skilled complex work due to their education and cognitive abilities (Card and DiNardo, 2002; Autor et al., 2003). This means, that the accomplishment of tasks "demanding flexibility, creativity, generalized problem-solving, and complex communications" (Autor et al., 2003, p.1284) becomes more important. Complex tasks, so far, posed a challenge for automation, because they required procedural and often implicit knowledge (Polanyi, 1966; Autor, 2015). However, recent technological developments such as machine learning, are capable of delivering heuristic responses to complex cognitive tasks by applying inductive thinking or big data analysis (Autor, 2015). Regarding complex manual tasks, mobile robots are increasingly equipped with advanced sensors which enable them to navigate through dynamic environments and interactively collaborate with human employees (Cascio and Montealegre, 2016).

In sum, economic research following the task-based approach argues that technology affects the routineness and complexity of work by substituting routine tasks. However, new technologies may be able to increasingly substitute and complement not only routine tasks, but complex tasks as well. According to the theories, this will again increase the complexity of work by creating new demands for problem-solving and reviewing the technology´s activity.

Useful insights can be gained from psychological theories that explicitly take the role of work characteristics into account. Work characteristics are often mentioned by for instance sociological theories (e.g. autonomy and meaningfulness) without clearly defining the concepts. Particularly the job characteristics model of Hackman and Oldham (1975) and the job-demand-control model of Karasek (1979; Karasek et al., 1998) are consulted to further clarify the meaning of autonomy and meaningfulness at work.

With regard to autonomy, Hackman and Oldham´s model (1975) conceptualizes autonomy as a work characteristic, defined as "the degree to which the job provides substantial

freedom, independence, and discretion to the employee in scheduling the work and in determining the procedures to be used in carrying it out" (Hackman and Oldham, 1975, p.162). According to the authors, autonomy facilitates various work outcomes, such as motivation and performance. In a similar vein, Karasek et al. (1998) stress the role of autonomy in the form of "decision authority" that interacts with more demanding work characteristics, such as workload or frequent interruptions and therefore enables a prediction of job strain and stress (Karasek et al., 1998). With regard to meaningfulness, Hackman and Oldham (1975) clarify that different core job dimensions, such as the significance of one´s own work results for the work and lives of other people, the direct contribution to a common goal with visible outcomes, and the employment of various skills, talents and activities all enhance the perception of meaningfulness at work.
In sum, psychological theories on employee motivation and stress clarify the concepts of autonomy and meaningfulness by illustrating the factors that contribute to their experience in relation to challenging and rewarding aspects of work.

Components of CVET

In order to formulate the implications for CVET of the studied effects of technology on work characteristics, a framework with the different components of CVET is needed. The objective of the VET system and continuous education is to qualify people by supporting the acquirement of required competences, for instance by providing training. Competences refer to the potential capacity of an individual in order to successfully carry out work tasks (Ellström, 1997). They contain various components such as work-related knowledge and social skills (e.g. Sonntag, 1992). Competences are considered here as "the combination of knowledge, skills and attitude, in relation to one another and in relation to (future) jobs." (Mulder and Baumann, 2005, p. 106; e.g. Baartman and de Bruijn, 2011).
Participants in CVET enter the system with competences, such as prior knowledge, motivation and expectations. It is argued that these have to be considered when designing learning environments for CVET. Next to making the distinction between the different components of learning environments content, guidance, method, and assessment, it is considered important that these components are coherent and consistent (Mulder et al., 2015). For instance, the content of the training needs to fit to the objectives and the background of the participants. The same goes for the method or didactics used (e.g. co-operative learning, frontal instruction) and the guidance of teachers, mentors or trainers. In addition, assessment needs to be consistent with all these components. For instance, problem based learning or competence based training requires other forms of assessment than more classical teacher centred forms of didactics, which makes a classic multiple choice test not fitting (Gulikers et al., 2004). Figure 3 contains an overview of the components of learning environments for CVET.

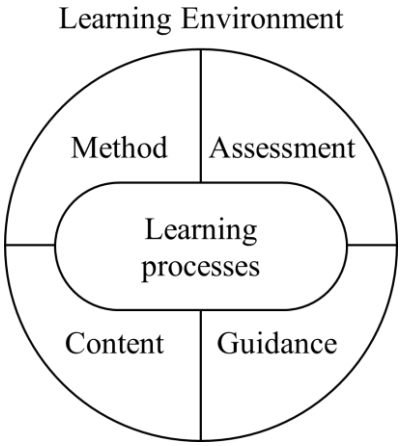

Figure 3. *Components of CVET learning environments (adapted from Mulder et al., 2015, p. 501)*

4.3 Methods

Three steps are necessary to answer the research questions. Firstly, a systematic search and review of empirical studies reporting evidence on the direct relationships between new technologies and work characteristics. Secondly, an analysis of the evidence with regard to its implications for work demands. Thirdly, deriving the work demands and their implications for CVET.

Systematic search strategy

Due to the interdisciplinary nature of our research, specific databases were selected for each of the disciplines involved: Business Source Premier (business and management research) and PsycArticles (psychology) were searched via EBSCOhost, and ERIC (educational science), and Sociological Abstracts (sociology) were searched via ProQuest.

Identifying suitable keywords for technological concepts is challenging due to the rapidly changing and inconsistent terminology and the nested nature of technological concepts (Huang et al., 2015). Therefore, technological terms were systematically mapped by using the different thesauri provided by each of the chosen databases. After exploding a basic term within a thesaurus, the resulting narrower terms and related terms were documented and examined within the following procedure: (a) Checking the compatibility with our definition of technology reflecting its instrumentality, (b) Adjustment of keywords that are too broad or too narrow, (c) Disassembling nested concepts. The procedure was repeated stepwise for each of the databases. Finally, 45 terms that reflect new technologies were documented and used for the database search.

Keywords reflecting work characteristics are derived from the theoretical conceptualisations previously outlined. Synonyms for different concepts within the relevant theories were identified and included. In order to narrow our search results, additionally operators for empirical studies conducted in a workplace setting were added.

Table 1
Final search string

	Search terms
Search terms for technology (Subject terms)	"artificial intelligence" or robot* or "big data" or computer* or "mobile device" or "wearable technology" or "implant" or "cloud computing" or "virtual reality" or "augmented reality" or blockchain or "automated manufacturing" or wireless or "data processing" or "real-time" or smart or cyber* or "assistive technology" or "instant messaging" or "social media" or "mobile communication" or ICT* or "information and communication technology" or "machine learning" or avatar* or "RFID" or "digital device*" or "mobile device*" or virtual* or "autonomous driving" or digitization or digitalization or digitisation or digitalisation or "information technology" or internet or smartphone or sensor* or "cyber-physical-system" or "internet of things" or IoT or "mobile internet" or "cloud technology" or "automated system" or "workplace automation"
	AND
Search terms for work characteristics	Meaning* or meaningfulness or complexity or flexibility or routine* or "non-routine*" or "job demand" or intensity or workload* or workflow or pressure or privacy "skill variety" or "task variety" or "skill diversity" or "task diversity" or responsibility or autonom* or control* or "decision-making" or freedom or alienation or identity or power or competition or uncertainty or "job characteristics" or "work characteristics" or "task characteristics" or "work environment"
	AND
Restriction: Empirical evidence (Abstract)	empirical* or quantitative or qualitative or survey* or "case study" or questionnaire* or interview* or evidence
	AND
Restriction: Work context	workplace or job or career or employment

In order to avoid unnecessary redundancy, the use of asterisks was carefully considered, provided that the search results did not lose significantly in precision or the number of hits did not grow to an unmanageable number of studies. The final search string is shown in Table 1.

Eligibility Criteria and Study Selection

Technical criteria included methodological adequacy. This was ensured by only including studies published in peer-reviewed journals. In addition, the studies had to provide quantitative or qualitative data on relationships between technology and work characteristics. Only English-language studies were considered, because most of the studies are published in English and therefore the most complete overview of the existing knowledge on this topic can be obtained. This also enables as many readers as possible to have access to the original studies and analyse the findings of the empirical studies themselves. Concerning technology, variables had to express the direct consequence or interaction with a certain technology (e.g. the amount of computer-use or experience with robots in the workplace) and indirect psychological states that conceptually resulted from the presence of the technology (e.g. a feeling of increased expectations concerning availability). Regarding work characteristics, variables had to describe work-related aspects associated with our

conceptualization of work characteristics (e.g. a change in flexibility or the perception of complexity).
Regarding the direction of effects, only studies that focused on the implementation or use of technologies for work-related purposes were included. Studies were excluded, if they (a) tested particular designs or features of technologies and evaluated them without considering effects on work characteristics, (b) regarded technology not as a specific tool but an abstract process (e.g. "digital transformation"), (c) were published before 1990 due to the fact that the extent of usability and usefulness of technologies before that time should be substantially limited compared to today (e.g. Gattiker et al., 1988), and (d) investigated the impact of technologies on society in general without a specific relation to professional contexts (e.g. McClure, 2018).
Studies that were found but that did not report empirical findings on the relationships between technology and work characteristics, but rather on the relationships between technology and work demands (e.g. specific knowledge or skills) or work outcomes (e.g. performance, job satisfaction) were documented. Since the aim for this study was to derive the work demands from the work characteristics in any case, the studies that reported a direct empirical relationship between technology and work demands were analysed separately (N = 7).

Data Extraction
The variables expressing technology and work characteristics were listed in a table, including the quantitative or qualitative data on the relationships. Pearson´s r correlations were preferred over regression results to ensure comparability. For qualitative data, the relevant passages documenting data were included. Finally, methodological information as well as sample characteristics and size are listed.

Analysis of the Results
Firstly, the variables containing work-related aspects are clustered thematically into a comprehensive final set of work characteristics. This is necessary to reduce complexity due to variations in naming, operationalisation and measurement and to make any patterns in the data more visible. Deviations from the theoretically expected clusters are noted and discussed before synthesizing the evidence narratively in accordance to the research questions (Rodgers et al., 2009). As proposed, the evidence on changing work characteristics is analysed with respect to the resulting work demands in the sense of knowledge, skills, attitude and behaviour, which in turn are used to determine the implications for the different components of CVET.

4.4 Results

Figure 4 depicts a flowchart documenting the literature search. In sum, 21 studies providing evidence on relationships between technology and work characteristics were included. In addition, seven supplementary studies containing empirical evidence on relationships

between technology and specific work demands were identified. These studies are taken into account when deriving the work requirements. Next, the descriptive characteristics of the included studies will be reported. After that, the evidence on relationships between technologies and work characteristics of the 21 included studies will be summarized, before finally deriving the work demands based on the evidence found.

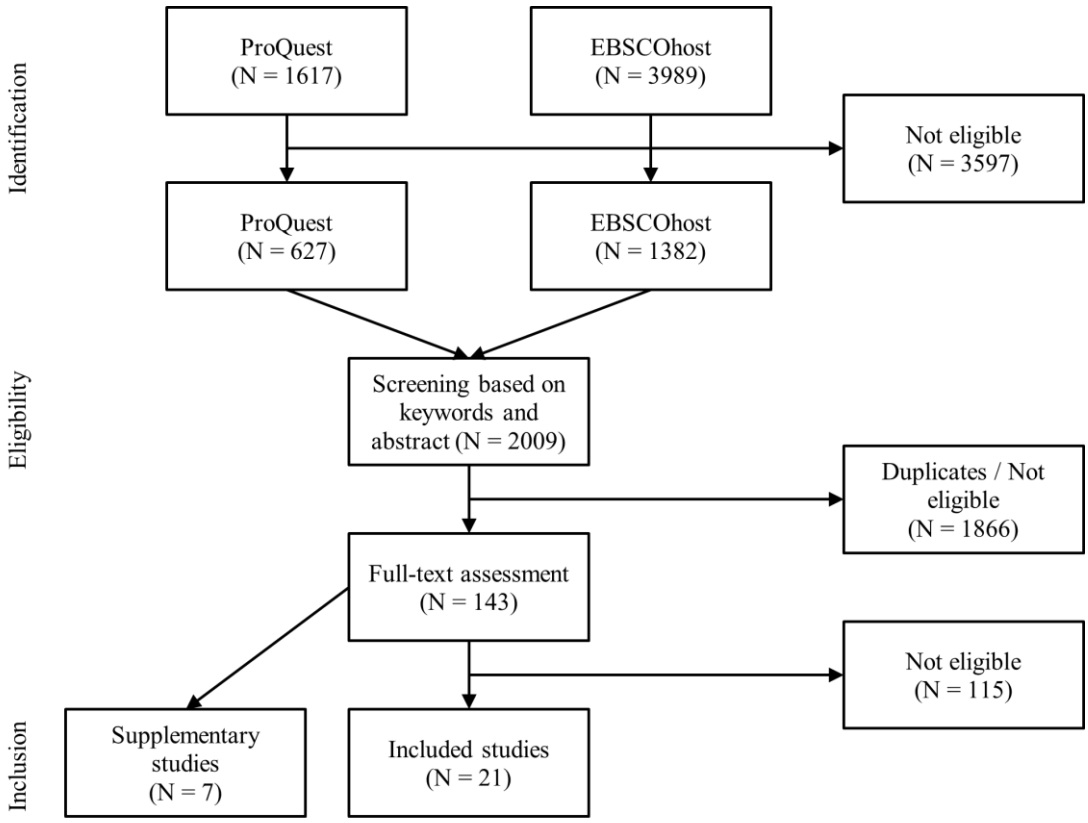

Figure 4. *Flowchart of literature search process*

Characteristics of studies

Table 2 contains an overview of the characteristics of selected studies. Most of the studies were published between 2015 and 2019 (52%). Nearly half of the studies were conducted in Europe (48%), followed by North America (33%). Most of the studies reported qualitative data collected with methods such as interviews (62%).

The studies investigated a variety of technologies, such as computers (1,7), various forms of Information and Communication technologies (ICTs; 2,3,17,18,21) in a broad sense, including specific examples of work-extending technologies and other tools for digital communication, information technology (IT) systems supporting information dissemination and retrieval within organisations (4,9), automated systems supporting predominantly physical work procedures (5,6,11,12,13,14,20), robots (15,19), social media enabling professional networking and participation in organisational and societal practices (8,16), and

more domain-specific technologies such as clinical technology supporting professional decisions (9) and field technology for labour management (10).

Table 2
Characteristics of the Studies

Characteristic	Number of studies
Publication year	
2015-2019	11
2010-2014	7
2005-2009	1
2000-2004	1
1990-1999	1
Domain	
Health care / Pharmaceutical industry / Therapy	5
Telecommunication / Technology	2
Manufacturing / Automobile / Port terminal	4
Accounting / Government / Postal service	3
Various	7
Origin	
North America	7
Asia	1
Europe	10
Australia	2
Africa	1
Design	
Survey study	6
Secondary analysis	2
Interview study	5
Case study	3
Action research	1
Other qualitative approach	4
Instruments	
Questionnaires	9
Interviews	10
Focus groups	3
Observations	2
Internal data (documents, log-data)	2
Workshop discussion	1
Data	
Quantitative	8
Qualitative	13

Note. $N = 21$

Relationships between technology and work characteristics

In sum, nine work characteristics were identified and defined distinctively. Table 3 contains the operational definitions of the final work characteristics and the work-related aspects they consist of. The final work characteristics are: Workflow interruptions, workload, manual work, mental work, privacy, autonomy, complexity, role expectations, and opportunities for

development. The complete overview of the selected studies and results for the relationships between technology and work characteristics is provided in Table 4 (for quantitative data) and Table 5 (for qualitative data). To further increase comprehensibility, the variables within the tables were labelled according to their function in the respective study (e.g. independent variable, mediating variable, dependent variable; see note).

Table 3
Overview for final work characteristics and the exemplary work-related aspects assigned to them

Work characteristic	**Operational definition**	**Examples of measured work-related aspects affected by technology**
Workflow interruptions	Extent to which employees can focus on a single task and avoid interruptions	Level of interruptions Quality of workflow Quality of communication processes Level of multitasking Need for multitasking
Workload	Amount and pace of work	Work overload Job demands (workload pressure) Work pressure Level of job speed Time pressure
Manual work	Extent to which the environment is characterised by physical tasks and requirements	Facilitation of physical tasks Content and scope of routine work tasks Amount of physically demanding tasks Physical demands
Mental work	Extent to which the environment is characterised by mental/cognitive tasks and requirements	Diagnosing and navigating demand Amount of monitoring tasks Problem-solving demand New challenging mental tasks
Privacy	Extent to which employees have control over their public image and their personal data at work	Invasion of privacy Perceived managerial surveillance Managerial tracking of behaviour Control over work-related data Peer-monitoring
Autonomy	Extent to which there is discretion regarding the type, order, methods, or time in which work needs to be done	Method-order autonomy Job decision latitude Time-method control Flexibility Instant accessibility of people and knowledge Job enrichment
Role expectations	Extent to which the job matches one´s own and others´ expectations regarding the role and the meaning associated with it	Role ambiguity Role expansion Role specific inner obligation for availability Connectivity or networking pressure Production responsibility Meaningful content of work
Complexity	Extent to which there is a lack of structure and transparency resulting from highly diverse and interconnected tasks and the associated ambiguity	Complexity Job complexity Situational awareness
Opportunities for development	Extent to which work provides opportunities for self-development and the need for development of skill and knowledge	Opportunities for skill and knowledge-acquisition Opportunities for professional development Continuous qualification demands Requirement to stay up to date with new technologies

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Table 4

Studies providing quantitative evidence for the relationship between technology and work-related aspects

	Relationship between technological and work-related aspects					Methodology		
	Technology under study	**Expression of technology**	**Work-related aspects**	**Correlation/ Effect**	**Work characteristics**	**Study Design**	***N* (Domain)**	**Reference**
1	Computer	Amount of computer work (IV)	Workload (IV)	r = .06**	Workload	2, b, i	N = 18723 (various domains; Europe)	Kraan et al. (2014)
			Method-order autonomy (IV)	r = .21**	Autonomy			
		Technological pacing (IV)	Workload	r = .20**	Workload			
			Method-order autonomy	r = -.19**	Autonomy			
2	ICT	Presenteeism (IV)	Invasion of privacy (ME)	r = .13**	Privacy	1, a, i	N = 661 (Various domains; United States)	Ayyagari et al. (2011)
			Work overload (ME)	r = .19**	Workload			
			Role ambiguity (ME)	r = .14**	Role expectations			
		Anonymity (IV)	Invasion of privacy	r = -.32**	Privacy			
			Work overload	r = -.14**	Workload			
			Role ambiguity	r = -.08	Role expectations			
		Pace of change (IV)	Invasion of privacy	r = .16**	Privacy			
			Work overload	r = .20**	Workload			
			Role ambiguity	r = .25**	Role expectations			
3	ICT	Email usage beyond the workplace (IV)	Job decision latitude (DV)	B = 0.02	Autonomy	1, a, i	N = 703 (various domains; United States)	Chen and McDonald (2015)
		Phone usage beyond the workplace (IV)	Job decision latitude	B = 0.13*	Autonomy			
		Positive ICT impacts (Productivity, flexibility, collaboration, connection) (IV)	Job decision latitude	B = 0.97*	Autonomy			
		Negative ICT impacts (long hours, job stress, stickiness, distraction) (IV)	Job decision latitude	B = -0.14*	Autonomy			
4		Frequency of computer usage (IT use) (IV)	Complexity after ERP implementation (DV)	r = .37*	Complexity	1, a, ii	N = 44 (Accounting)	Marler and Liang (2012)

Table 4

Studies providing quantitative evidence for the relationship between technology and work-related aspects

	Relationship between technological and work-related aspects					Methodology		
	Technology under study	**Expression of technology**	**Work-related aspects**	**Correlation/ Effect**	**Work characteristics**	**Study Design**	***N* (Domain)**	**Reference**
	Information technology system (ERP)	ERP use (IV)	Complexity after ERP implementation	r = .33*	Complexity			
5	Letter sorting machine	Machine-paced work (IV)	Autonomy (ME)	r = -.46**	Autonomy	1, a, i	N = 4682 (postal service industry; United States)	Amick and Celentano (1991)
			Job demands (Workload pressure) (ME)	r = .32**	Workload			
6	Automated Manufacturing Technology	Technological coupling (Complexity of machine) (IV)	Time method control (IV)	r = -.23*	Autonomy	1, a, i	N = 216 (Manufacturing; Isreal)	Dvash and Mannheim (2001)
			Monitoring demand (IV)	r = .01	Mental work			
			Problem-solving demand (IV)	r = .03	Mental work			
			Production responsibility (IV)	r = .11	Role expectations			
			Job enrichment (IV)	r = .08	Autonomy			
7	Computer	Daily computer-use for work (IV)	Level of job speed (ME)	B = 0.14*	Workload	2, a, i	N = 2556 (various domains; United States)	Chesley (2014)
			Level of job interruptions (ME)	B = 0.48**	Workflow interruptions			
			Level of multitasking (ME)	B = 0.31**	Workflow interruptions			
			Job autonomy (CV)	r = .07†	Autonomy			
			Job complexity (CV)	r = .14†	Complexity			
8	Social media	Frequency of social networking service use for work-related communication (IV)	Work pressure (ME)	r = .32*	Workload	1, a, i	N = 364 (telecommunication and consulting; Netherlands)	van Zoonen and Rice (2017)
			Autonomy (ME)	r = .14*	Autonomy			

Note. IV = Independent variable, ME = Mediating variable, DV = Dependent variable, CV = Control variable; r = Pearson´s r correlation; B = unstandardized coefficients; Concerning methodology: 1 = survey; 2 = secondary analysis; a = questionnaires; b = interviews; i = cross-sectional; ii = longitudinal / multiple measurements; *p < .05; **p < .01; †No level of significance reported;

Table 5

Studies providing qualitative evidence for the relationship between technology and work-related aspects

	Technology	Research objective	Work-related aspects affected by technology	Work characteristics	Study Design	*N* (Domain)	Reference
9	Clinical technology (CT)	Exploration of nurses´ perceptions of new technology in relation to their skills, autonomy and experience of work	Increased workload due to higher efficiency and patient flow rates accomplished by CT use	Workload	1, a, i	*N* = 125 (Nursing; Australia)	Gough et al. (2014)
			Increased complexity of interventions due to enhanced treatment potential	Complexity			
			Enhanced opportunities for clinical knowledge- and skill-acquisition due to clinical information provided by CT in a high dependency environment	Opportunities for development			
	Information technology (IT)		Reduced content of work (e.g. time with patient care) due to higher reporting requirements by IT-system (resulting in time spent with technology)	Role expectations			
			No feeling of managerial surveillance or control by IT database	Privacy			
10	Field technology	Exploration if employees´ right for data privacy is challenged in the face of electronic governance and control by management	Increased control by management through continuous tracking of behaviour and performance and managerial allocation of work (labour management)	Privacy	1, a, e, i	*N* = 90 (Installation, cleaning, home care, security, transport; Norway)	Tranvik and Bråten (2017)
			Less control over work-related data by employees due to automatic and non-transparent data transmission	Privacy			
11	Automated terminals	Understanding how work, job roles and associated skills have changed across technological shifts	Facilitation and acceleration of routine and physical work tasks through process automation controlled by computer technologies	Manual work	4, a, d, ii	Unreported (Port terminal work; Australia)	Gekara et al. (2018)
			Higher diagnosing and navigating tasks within a digitised work environment including mobile and fixed digital devices	Mental work			
			Decreased content and scope of operational tasks and increase in monitoring tasks due to digital devices	Manual work			
12	Automated production systems	Exploration of the relationship between the quality of human-machine interaction and work satisfaction, workload and stress	Increased time pressure and need for multitasking due to technical interruptions	Workflow interruptions	1, a, i	*N* = 36 (Manufacturing industry; Germany)	Körner et al. (2019)
			Occasional low situational awareness due to increased system complexity and inadequate information	Complexity			
			Continuous qualification requirements to deal with complex computer-related problems and expectation of learning-by-doing	Opportunities for development			

Table 5

Studies providing qualitative evidence for the relationship between technology and work-related aspects

	Technology	Research objective	Work-related aspects affected by technology	Work characteristics	Study Design	*N* (Domain)	Reference
13	Bar-coded medication administration technology	Investigating the impact of automated medication administration technology on nurses´ problem-solving behaviour	Increased workload due to the technology blocking familiar problem-solving strategies	Workload	4, a, d, i	*N* = 17 for observations; *N* = 45 for interviews (Nursing; United States)	Holden et al. (2013)
			Increasing occurrence of new problems that require creative problem-solving and "workarounds" by using or bypassing the system	Mental work			
14	Automated dispensing system	Determining the effects of installing an automated dispensing system on staff experience of work, psychological contract, individual outcomes and future plans	Opportunities for role expansion due to the opportunity to approach new value-adding tasks through automation	Role expectations	2, c, ii	*N* = 31 (Pharmaceutical industry; United Kingdom)	James et al. (2013)
			Increasing physical demands for employees directly working with the system due to monotony and time pressures	Manual work			
			Reduction of roles for employees that support the system directly (e.g. technicians)	Role expectations			
15	Cobots	Identifying issues for the African workforce regarding the implementation of cobots	Decreased amount of physically demanding tasks due to physical support by cobots	Manual work	4, b, i	*N* = 12 (Automobile manufacturing; Africa)	Calitz et al. (2017)
			Increase in new and challenging mental tasks that require a certain understanding, acceptance and trust towards cobots	Mental work			
16	Social media	Explication of the boundary-related rules regarding personal and professional social media use at work	Perceived feeling of peer-monitoring and judgement in case of personal social media use (e.g. Facebook, Twitter)	Privacy	2, a, i	*N* = 29 (Technology sector; United States)	Walden (2016)
			Perceived pressure to network with peers and clients with professional social media due to acceptance and positive appraisal of work-related use (e.g. LinkedIn)	Role expectations			
17	Tools for digital communication	Determining the relationship between communication in the digital work environment and wellbeing at work, factors influencing the relationship, and its context	Interruption of workflow and attention due to the constant flow of messages and communication via various communication platforms and devices	Workflow interruptions	3, e, f, i	*N* = 36 (Industrial, insurance, finance)	Bordi et al. (2018)
			Requirement to stay up to date with new tools for digital communication due to changing technology and customer preferences	Opportunities for development			
			Increased flexibility (time, place, task) due to self-initiated multitasking and use of various tools	Autonomy			

Table 5

Studies providing qualitative evidence for the relationship between technology and work-related aspects

	Technology	Research objective	Work-related aspects affected by technology	Work characteristics	Study Design	*N* (Domain)	Reference
18	Work-extending technologies	Examining the effects of work-extending technologies on working time, relationships, and strategies employed by employees to deal with technological effects and its impact	Increased efficiency, productivity and flexibility (working from home or while traveling) if work extending technologies can be used	Autonomy	1, a, c, i	*N* = 61 (Government department; Canada)	Towers et al. (2006)
			Higher workload due to perceived expectations for constant availability and longer work days	Workload			
19	Robots	Exploring therapists´ needs regarding robots and functions that make robots perceived as useful	Potential workflow support if robots support repeatable tasks, observe behaviour and give objective feedback	Workflow interruptions	4, b, i	*N* = 21 (Autism therapy; Poland)	Zubrycki and Granosik (2016)
			No creation of opportunities to improve therapist value or for professional self-development by robots	Opportunities for development			
20	Robot-facilitated pharmacy distribution	Understanding to what extent employers considered job quality in advance to an automated system´s introduction and how those considerations impacted various aspects of job quality for employees	More opportunities for upskilling and interdisciplinary learning through job rotation as a consequence of the system´s introduction (in general)	Opportunities for development	2, a, c, i	*N* = 45 (Health care; United Kingdom)	Findlay et al. (2017)
			Increase in meaningful job content (less repetitive work, greater task variety, more interaction with colleagues and patients) for ward-based employees whose work is strongly supported by the automated system (i.e. ward-based technicians and support staff)	Role expectations			
			Higher paced, more repetitive and less skilled work for employees that support the system directly (i.e. dispensary technicians)	Role expectations			
			Less possibilities for learning and career development due to decreased opportunities for job rotation for some employees (i.e. dispensary technicians)	Opportunities for development			
21	ICT	Examination of specific stressors and benefits resulting from work-related technology-use in public relations, journalism and advertising	Regular interruptions of workflow due to constant availability via mobile communication	Workflow interruptions	1, a, i	*N* = 25 (Advertising, public relations, journalism; Austria, Hong Kong)	Ninaus et al. (2015).
			Connectivity pressure as a consequence of increased response expectations due to the mobile wireless communication	Role expectations			
			Inner obligation for availability as a result of being able to perform and compete at any time	Role expectations			

Table 5

Studies providing qualitative evidence for the relationship between technology and work-related aspects

Technology	Research objective	Work-related aspects affected by technology	Work characteristics	Study Design	*N* (Domain)	Reference
		Improved workflow and improved communication as a result of instant communication detached from workplace and working time	Workflow interruptions			
		Instant accessibility of people and knowledge as a result of flexible device-use and integration of various digital platforms and devices	Autonomy			
		Increased flexibility as a result of mobile technologies allowing to autonomously allocate working time and place	Autonomy			

Note. Concerning methodology: 1 = interview study; 2 = case study; 3 = action research; 4 = other qualitative approaches; a = interviews; b = questionnaire; c = focus groups; d = observations; e = internal data (documents, log-data); f = workshop-discussion; i = cross-sectional; ii = longitudinal;

Complexity. There is quantitative evidence on positive relationships between IT system use and complexity reported by two studies (4, 9). On a similar note, qualitative evidence suggests lower situational awareness within automated systems indicating an increase in complexity (12), and clinical technology being associated with an increase in complexity for nurses (9).

Autonomy. There is mixed quantitative evidence on the relationships between computer work and autonomy (1). The amount of computer work is positively related to autonomy, while technological pacing is negatively related to autonomy. Working within automated systems is negatively (5, 6) or not related (6) to different measures of autonomy. ICT use shows mixed relationships with job decision latitude (3) depending on ICT features that describe negative or positive effects of use. Evidence indicates a positive relationship between social media use and autonomy. Qualitative evidence suggests that ICT use increases autonomy (21) and flexibility (17, 18, 21).

Workload. Quantitative studies indicate strong positive relationships between computer work (1) and ICT use (2) and workload. The relationships are not consistent due to the fact that certain ICT features differ in their effects on workload. ICT characteristics such as presenteeism and pace of change are positively related to feelings of increasing workload, while a feeling of anonymity is negatively associated with workload. Evidence indicates positive relationships between time or workload pressure in the context of computer work (7), working in an automated system (5), as well as social media use (8) and provide evidence for positive relationships between various technologies and workload. Qualitative studies report similar outcomes. ICT use (18), automated systems (12, 13) as well as clinical technology (9) are reported to increase the workload.

Workflow interruptions. Quantitative evidence indicates positive relationships between computer work and increasing levels of interruptions as well as an increasing demand for multitasking (7). Qualitative evidence suggests that ICT use is positively associated with an increased level of interruptions on the one hand and workflow support on the other hand (21). Further qualitative evidence suggests that robots at the workplace have positive effects on workflow support (19), and automated systems seem to increase the level of multitasking required in general (12).

Manual work. Qualitative evidence suggests a decrease in the amount of physically demanding tasks when working with automated systems (11) and robots (15). In one study, qualitative evidence suggests an increase in manual work for technical jobs where automated systems are used(14).

Mental work. Quantitative evidence indicates no relationships between monitoring tasks or problem-solving demands for technical jobs within automated systems (6). Qualitative evidence however suggests positive relationships between work within automated systems

and various cognitive tasks and demands, such as problem-solving and monitoring (11, 13), while working with robots increases the amount of new and challenging mental tasks (15).

Privacy. Quantitative evidence indicates that different ICT characteristics show different relationships with invasion of privacy (2). Some features are negatively related to invasion of privacy (anonymity) and others are positively related to it (presenteeism, pace of change). Qualitative evidence suggests that IT systems are not related to the perception of managerial surveillance (9), while social media is positively related to peer-monitoring (16) and field technology is negatively related to employee data control (10).

Role expectations. Quantitative evidence indicates that ICT use is inconsistently related to role ambiguity depending on specific characteristics of the technology (2). Regarding automated systems, quantitative evidence indicates no relationship between working in an automated system and opportunities for role expansion in the form of an increased perceived responsibility (6). Qualitative evidence suggests that ICT use increases the expectations for availability and connectivity (21), and social media positively affects networking pressure (16). Qualitative evidence suggests that IT systems (9) decrease meaningful job content and role expansion. Qualitative evidence suggests that automated systems vary with regard to enhancing meaningfulness at work, dependent on whether the work tasks are complemented by the system or revolve around maintaining the system (20).

Opportunities for development. Qualitative evidence suggests that ICT use (12) as well as working with an automated system (17) increase the demands for continuing qualification. Qualitative evidence suggests that opportunities for learning and development are prevalent with clinical technology (9) and absent when working with robots (19). Mixed qualitative evidence regarding automated systems and learning opportunities suggests that the effects depend on the differences in work roles in relation to being supported by the system or supporting the system (20).

A comprehensive summary of the outcomes can be found in Table 6. The information in this table gives a summary of the evidence found for the different technologies and their relationships to work characteristics, more specifically to work related aspects. Important distinctive characteristics such as sample characteristics are listed in tables 4 and 5.

Table 6

Overview over identified relationships between technology and work characteristic

Number of study	Work-related aspects affected by technology (clustered)	Work characteristic	Computer	ICTs	IT systems	Automated systems	Social media	Clinical technology	Field technology	Robots
7, 17	Level of interruptions	Workflow interruptions	⊕	+						
19, 21	Support of workflow			− +						+
7, 12	Level of multitasking		⊕			+				
2, 1, 9, 13, 18	Workload	Workload	⊕ ⊕	⊕ ⊖ ⊕ +		+		+		
5, 8	Workload pressure / Work pressure					⊕	⊕			
7, 12	Level of job speed / Time pressure		⊕			+				
11	Facilitation of physical tasks	Manual work				−				
11, 15	Content, scope and amount of routine tasks					−				−
14	Physical demands					+				
11	Diagnosing and navigating demand	Mental work				+				
6, 11	Monitoring tasks / demand					∅ +				
6, 13	Problem-solving demand					∅ +				
15	New challenging mental tasks									+
2	Invasion of privacy	Privacy		⊕ ⊖ ⊕						
9, 16	Managerial- or peer surveillance				/		+			
10	Control over work-related data								−	
10	Managerial tracking of behaviour								+	
1, 6, 21	Method-order autonomy / Time method control	Autonomy	⊕ ⊖	+		⊖				
3, 6	Job decision latitude / Job enrichment			⊕ ⊕ ⊖ ∅		∅				
7	Job autonomy		∅							
5, 8	Autonomy					⊖	⊕			
17, 18, 21	Flexibility			+ + +						

Table 6

Overview over identified relationships between technology and work characteristic

Number of study	Work-related aspects affected by technology (clustered)	Work characteristic	Computer	ICTs	IT systems	Automated systems	Social media	Clinical technology	Field technology	Robots
2	Role ambiguity	Role expectations		⊕ ⊕ ⊘						
6, 14, 19	Role expansion					⊘ + −				−
21, 16	Availability, connectivity and networking pressure			+ +			+			
9, 20	Meaningful content of work				−	+ −				
4, 9	Complexity	Complexity			⊕ ⊕			+		
7	Job complexity		⊘							
12	Situational awareness					−				
9, 19, 20	Opportunities for learning, and professional development	Opportunities for development				+ −		+		−
12, 17	Continuous qualification demands			+		+				

Note. + = positive relationship, - = negative relationship, / = explicitly no relationship; Quantitative results are encircled; the total number of effects may exceed the number of studies reported due some studies reporting several different effects

Subsequently, the results shown are now used as a basis for the identification of work demands that lead to the need for adapting to changes in work characteristics.

Relationships between technologies and work demands

Three sources are considered for the identification of work demands: Work demands mentioned in the studies on technology and work characteristics, work demands mentioned by the supplementary studies found during the database search (N = 7), and work demands analytically derived from the results.

Some studies that examined the effects of technology on work characteristics also reported concrete work demands. Regarding the increasing complexity and the associated mental work, qualitative evidence suggests an increasing demand for cognitive as well as digital skills (11) in automated systems. With regard to IT systems, quantitative evidence indicates positive relationships with computer literacy (9), and analytical skills (4). With regard to the increase in workflow interruptions and the role expectations for constant availability and connectivity, time and attention management strategies are proposed in order to cope with the intrusive features of technology (2). Other strategies mentioned in the studies include self-discipline for disengaging from the ubiquitous availability resulting from mobile communication devices (18, 8) as well as the need for reflecting on individual responsiveness when working overtime due to self-imposed pressure to be available at all times (18, 21). Concerning opportunities for development, the willingness and ability to learn and adapt to technological changes and the associated changes in work (15, 4, 12) is emphasized. Moreover, employability is facilitated by using technological tools for professional networking (16).

The supplementary studies provide evidence on the direct relationships between technologies and work demands without the mediating consideration of work characteristics. This evidence is listed in Table 7.

Table 7

Supplementary studies on the relationship between technology and work-related demands

		Relationship between technological aspects and work-related demands			Methodology		
	Technology under study	**Perception of technology**	**Work-related demand**	**Correlation / Effect**	**Study Design**	***N* (Domain)**	**Reference**
22	Computer	Perception of controllability (IV)	Exploratory use (low enrichment environment) (ME)	*r* = .37**	1, a, i	*N* = 158 (Manufacturing, service, government organisations)	Ghani and Deshpande (1994)
			Exploratory use (high enrichment environment) (ME)	*r* = .66**			
23	Care robots	Negative impact on employment (IV)	Readiness for robotization (DV)	*r* = -.40**	1, a, i	*N* = 3800 (Home- and healthcare; Finland)	Turja et al. (2019)
		Experience in robot use (IV)	Readiness for robotization	*r* = .10**			
24	Robots	Daily internet use at work (IV)	Individual level robot acceptance at work (DV)	*B* = .40**	2, a, i	*N* = 53543 (various domains; Europe)	Turja and Oksanen (2019)
		Robot experience (IV)	Individual level robot acceptance at work	*B* = 1.20**			
25	Telemedicine technology	Perceived usefulness (IV)	Attitude (ME)	*PC* = .45**	1, a, i	*N* = 408 (Healthcare; Hong Kong)	Chau and Hu (2002)
		Perceived ease of use (IV)	Perceived Technology Control (ME)	*PC* = .11*			
26	Blockchain technology	Perceived usefulness (IV)	Attitude (ME)	*PC* = .86**	1, a, i	*N* = 181 (supply chain management; India)	Kamble et al. (2019)
		Perceived ease of use (IV)	Attitude (ME)	*PC* = -.01			
27	Information technology system	Perceived usefulness (IV)	Attitude (DV)	*r* = .64**	1, a, i	*N* = 204 (Nursing; Hong Kong)	Chow et al. (2012)
		Perceived ease of use (IV)	Attitude	*r* = .43**			

Table 7

Supplementary studies on the relationship between technology and work-related demands

		Relationship between technological aspects and work-related demands			Methodology		
	Technology under study	**Perception of technology**	**Work-related demand**	**Correlation / Effect**	**Study Design**	***N* (Domain)**	**Reference**
28	Various workplace technologies	Information demands (IV)	Cognitive skills (DV)	r = .47**	1, a, i	N = 184 (various domains; New Zealand)	Spell (2001)
			Interpersonal skills (DV)	r = .40**			
			Psychomotor skills (DV)	r = -.13			
		Programmability (IV)	Cognitive skills	r = .08			
			Interpersonal skills	r = .18*			
			Psychomotor skills	r = -.02			
		Number of exceptions (IV)	Cognitive skills	r = .32**			
			Interpersonal skills	r = .31**			
			Psychomotor skills	r = -.15			

Note. IV = Independent variable, ME = Mediating variable, DV = Dependent variable, CV = Control variable; r = Pearson´s r correlation; B = unstandardized coefficients; Concerning methodology: 1 = survey; 2 = secondary analysis; a = questionnaires; i = cross-sectional; ii = longitudinal / multiple measurements; *p < .05; **p < .01;

There is quantitative evidence for positive relationships between the perception of controllability and exploratory use of computers (22), first-hand experience with robots and readiness for robotization (23, 24), and perceived usefulness and positive attitudes towards telemedicine technology (25), blockchain technology (26), and IT systems in general (27). Further quantitative evidence indicates mixed effects of perceived ease of use. Evidence indicates a positive relationship between perceived ease of use and perceived technological control with regard to telemedicine (25), no relationship between ease of use and attitude regarding blockchain technology (26), and a positive relationship between ease of use and attitude towards using IT systems (27). Quantitative evidence indicates that information processing enabled by technology is positively related to an increasing demand of cognitive skills (e.g. synthesizing and interpreting data) and interpersonal skills (e.g. coordinating and monitoring other people), but not related to an increasing demand in psychomotor skills (e.g. manual producing and precise assembling) (28). The level of standardisation of work is positively related to interpersonal skills, but not related to cognitive and psychomotor skills (28). A high variety of tasks is positively related to the demand for cognitive skills and interpersonal skills and not related to psychomotor skills (28).

By analysing the evidence on relationships between technology and work characteristics, further work demands can be derived. Knowledge about the specific technology at hand may be useful to decrease the perception of complexity as new technologies are introduced. This seems evident when comparing the effects of a simple computer with the effects of work within an automated system. For instance, while evidence indicates no relationship between computer work and complexity (6), work within an automated system is suggested to be associated with increasing complexity (12). Moreover, problem-solving skills (13) and cognitive skills such as diagnosing and monitoring (11, 15) increase when employees work within automated systems. Increasing autonomy suggests the need for personal skills regarding self-organizing and self-management due to greater flexibility and the associated possibilities for structuring work in many ways, particularly when working with ICTs (18, 21). Workflow interruptions and an increasing workload also increases the importance of communication skills for explicating the boundaries of one´s own engagement to colleagues and leaders (17, 18, 21). Furthermore, reflecting the professional role at work may be critical due to changes in role expectations. The example of self-imposed need for availability underlines this argument (21). All this has implications for self-regulatory activities, such as reflection, and could benefit from experimenting and monitoring one's own strategies for time and attention management.

Implications for CVET: objectives and characteristics

The aforementioned studies describe several required behavioural aspects that are considered important due to technology at work. Emphasized is the need for components related to the organisation of one's own work, namely self-discipline and time and attention management.

The identified need for reflection on one´s own professional actions, for experimentation, and also for professional networking (for instance by using tools) can be seen as parts of

further professional development by oneself or in interaction with others. In addition, the need for demonstrating employability is mentioned. From all these professional and career development aspects can be derived that problem-solving skills, self-regulation skills and communication skills are required as well as proactive work behaviour and coping and reflection strategies.

Various relevant skills, such as psychomotor skills, analytical skills, management skills and interpersonal skills are mentioned. In addition, the need for diagnostic and monitoring skills as well as digital skills is emphasized. All these components can be used in relation to two explicitly mentioned needs: ability to learn and computer literacy. The demand for generic and transferable skills is emphasized. As a basis for the skills, knowledge is required, for instance on the technology itself, although not explicitly discussed in the studies. In contrast, several components of attitude are explicitly mentioned and considered to be a requirement for the ability to deal with challenges caused by new technologies at work. Firstly, the more generic willingness to learn, adaptability, and perceived behavioural control. Secondly, attitudes that are directly linked to technology, namely a positive attitude and trust, especially towards technology (e.g. robots), and technological readiness and acceptance.

Next to the opportunity of acquiring the mentioned components of competences at work, CVET can organise training interventions in the form of adequate learning environments to foster these. The ability of employees to carry out, develop and use the mentioned behavioural aspects, skills, knowledge and attitudes, can be considered as required objectives of CVET and have concrete consequences for the characteristics of the learning environments.

As for the content of the learning environments, derived from the aforementioned requirements, it can be argued that attention should be paid to different categories of learning objectives: acquiring knowledge about and learning how to use technology, how to manage work and oneself, and how to continue one's own professional development. In addition, the relevance of attitude tells us that these components need to be fostered in the training and therefore need to be part of the content of the learning environments as well.

In relation to the methods or the didactics, only one study explicitly mentioned a suggestion, namely experience based learning for fostering adaptability (12). In relation to the guidance of trainers or teachers no suggestions are provided. The same goes for assessment, diagnoses or monitoring, and the coherence of components of the learning environments.

4.5 Discussion

This systematic literature review aimed at identifying effects of new technological developments on work characteristics, identifying associated work demands and determining their implications for the design of formal CVET learning environments.

Effects of new technologies on work characteristics and work demands

Based on a systematic review focusing on empirical evidence, several effects of technology on work characteristics were found, thus answering RQ 1. Evidence suggests that complexity and mental work increases with ongoing automation and robotization of work, for instance due to the automatization of procedures which "hides" certain processes from employees. The automatization of tasks introduces new mental tasks, such as monitoring the machine´s activities and solving problems. A decrease in manual work depends on the relation between the job and the technology in use (supporting vs. being supported).

Workload and workflow interruptions increase as a general consequence of the ubiquity of technology, mainly due to a higher level of job speed and the associated time and workload pressure. A higher level of autonomy seems to be associated with a higher workload and more workflow interruptions. This applies in particular to work with ICTs and domain-specific technologies, such as field technology.

Role expectations and opportunities for development depend on the relation between the job and the technology in use (supporting vs. being supported). With regard to role expectations, the need for being available or connected via digital devices and a new division of responsibilities between employees and technology are repeatedly mentioned in the studies. This applies particularly to work with automated systems, robots, and domain-specific technologies such as clinical technology.

With regard to work demands, employees need strategies to deal with higher levels of workload, autonomy and complexity. Required skill demands contain mental, analytical, cognitive and self-regulatory demands. In addition, opportunities for role expansion and learning, which do not seem to automatically result from the implementation and use of new technologies, need to be created (pro)actively by the employees. Employees need to take more responsibility with regard to their own development and professional work identity (for instance considering the pressure for constant availability). They need to be able to effectively deal with a high workload and number of interruptions, increasing flexibility, complexity and autonomy, a demand for constant availability, changes in meaningfulness of tasks, changes in work roles, and the need to create and use learning opportunities. In the light of ongoing changes and challenges, skills to further develop and adapt one´s own skills gain in importance. Regarding attitudes, the willingness to learn, adapt and experiment may be a central work demand.

Implications for the practice of CVET

Various required objectives of CVET can be concluded from the reported results. For instance, developing the ability of employees to carry out the mentioned behaviours, as well as the skills, knowledge and attitudes that are necessary for those behaviours. These objectives have consequences for the content of CVET learning environments. From the empirical studies on the relationships between technology and work, we derived the need for employees to organise their own work, for instance through time management. Furthermore, many issues relating to own professional development and career development are important, to acquire individually and independently as well as by interacting with others.

Ultimately, this refers to the skills of self-initiated learning and development. With regard to fostering helpful attitudes, raising awareness of the relevance of trust or training the social skills to promote trust in the workplace can be included in the content of CVET learning environments. In research on creating trust within organisations, regularly giving and receiving relevant information was shown to be important for creating trust towards co-workers, supervisors and top-management, which in turn fostered the perception of organisational openness and employee involvement as a result (Thomas et al., 2009). In the research on creating trust in virtual teams, the importance of frequent interaction was important to develop trust on a cognitive as well as an affective level (e.g. Germain, 2011). These research results however need to be adapted to the context of technology at work.
Although there is no information provided on the guidance of employees, informal guidance through leadership (Bass and Avolio, 1994) as well as formal guidance by trainers and teachers during interventions contain possibilities for fostering the required competences. Attention should be paid not only to acquiring relevant knowledge (digital literacy), but also to skills in applying the knowledge and therefore dealing with technology. Even more challenging might be the task of supporting attitude development (e.g. technological acceptance and openness to changes), fostering transfer of skills, and preparation for future development. Especially future professional development, which includes the ability to learn in relation to current and future changes, needs to be focused on. Teachers, trainers and mentors need to be equipped to be able to foster these competences.

In relation to the use of didactical methods, methods that do not merely focus on knowledge acquisition but also provide opportunities for skill acquisition and changes in attitude need to be applied. For example, one study explicitly suggested experience based learning for fostering the adaptability of employees when faced with ongoing technological developments. Other solutions for instruction models as a profound basis for learning environments may be found in more flexible approaches, for instance according to the cognitive flexibility theory (Spiro et al., 2003), where learners are meant to find their own learning paths in ill-structured domains. By applying such models, that are often based on constructivist learning theories, in a coherent way, the development of strategies for self-organising and self-regulation may be facilitated.
Furthermore, the use of technology within learning environments may have the potential to increase participant's interactions, which are focused in for instance collaborative and co-operative learning (Dillenbourg et al., 2009). Next to increasing interactions in learning and being able to co-operate, technology in learning environments can be used to foster the other required competences, if adequately designed (Littlejohn and Margaryan, 2014; Vosniadou et al., 1996).
When keeping in mind, that the coherence of components is an important requirement for the design of learning environments (Mulder et al., 2015), the component that describes assessment needs further attention. There is evidence supporting the idea, that the type of assessment has an impact on how learning takes place (Dolmans et al., 2005; Gulikers et al., 2004). Therefore, it can be used to deliberatively support and direct learning processes.

Only when all these aspects are considered can CVET interventions effectively and sustainably foster the mentioned objectives, such as promoting a willingness to change in relation to technologies, the effective use of technology, and personal development in the context of technological developments.

Limitations and implications for future research

Regarding the search methods, the use of databases is challenging when investigating technologies (Huang et al., 2015). Technological and technical terms are widespread outside the research in which they are regarded as the object of investigation. Therefore, it produces a large amount of studies that concern technology with diverse research objectives that can be difficult to sort. An interesting focus for future research would be the systematic mapping of journals dealing specifically with technology in order to identify research that could complement the results of the present study as well as consider specificities regarding the domains in which the data is collected and disciplines by which the research is conducted. For instance, domain-specific databases from healthcare or manufacturing might provide additional insights into the effects of technology on work. Another limitation is the absence of innovative new technologies, such as artificial intelligence, blockchain, or the internet of things as object of investigation. Broad technological categories, such as ICTs and social media have received some attention in research, especially in relation to questions beyond the scope of this review. Newer technological developments as discussed by Ghobakhloo (2018) are virtually not present in current research. This gap in empirical research needs to be filled. In addition, future research should ensure that it does not miss opportunities for research where effects of these innovative technologies can be examined in detail, for instance by conducting an accompanying case study of the implementation process. Research investigating changes over time regarding the use of technology and its effects is needed. In doing so, research could capture the actual dynamics of change and development of processes as they happen in order to inform truly effective interventions in practice. Moreover, a classification of technological characteristics according to their effects may be valuable by enabling a more in-depth analysis of new technologies and their effects on specific groups of employees and different types of organisations. These analyses will also allow a breakdown of effects in relation to differences in jobs, hierarchy levels and levels of qualification, which could be very important for organisations and employers in order to adapt the CVET strategy to the specific demands of specific groups of employees. The present review takes a first step in this direction by identifying work characteristics that are affected by different technologies. In addition, future research could also take into account non-English language research, which might increase insight in for instance cultural differences in the use and the effects of technology at work.

Regarding theory, some of the relevant theories considering technology stem from sociology (e.g. Braverman, 1998) or economics (Autor et al., 2003). For instance, the task-based approach (Autor et al., 2003) showed some explanatory value by suggesting that complexity may increase as a consequence of technology. Furthermore, it suggested that this effect may depend on job specifics. Those propositions are reflected in the aforementioned empirical

evidence. Psychological theories on work characteristics do not conceptualize technology explicitly (e.g. Karasek, 1979; Hackman and Oldham, 1975). As of the present study, the large variation regarding the concepts and variables derived from theory might limit the comparability of results. To foster systematic research, further theory development needs to more explicitly consider the role of technology at multiple levels (i.e. individual level, team level, organisational level) and with regard to the characteristics and demands of work. In the context of theory, the paradigmatic views also deserve attention (e.g. Liker, Haddad and Karlin, 1999; Orlikowski and Scott, 2008). These views could be reflected in the subject of research, as exemplified for instance in the study of field technologies and its effects on privacy from a managerial control and power perspective, potentially reflecting the view of political interest (Tranvik and Bråten, 2017). Most of the studies, however, do not take a clear stand on what exactly they mean when they investigate technology. This complicates interdisciplinary inquiry and integration, as it is not always clear which understanding of technology is prevalent. We therefore encourage future research to explicitly define technology, for instance as in the present paper using the proposed framework of McOmber (1999). In doing so, characteristics of technology may be defined more clearly and distinctive which in turn would enable the formation of the strongly needed categorisation of technologies, as was proposed earlier. And, although there are theories and models on the use of technology in education (e.g. E-Learning, Technology enhanced learning), they are not focussing on fostering the competences required to deal with new technologies in a sustainable manner. In general, the same gap needs to be filled for instruction models and instructional design models, for instance to promote changes in attitude and professional development. In addition, there is hardly any attention for the consequences of new technologies at work for CVET yet (Harteis, 2017). All this requires more systematic evaluation studies. The research gaps identified need to be filled in order to provide evidence-based support to employees in dealing with new technologies at work in a sustainable manner, taking charge of their own performance and health, as well as seeking and using opportunities for their own professional and career development.

5 Study 2: The meaning of the relationships between new technologies, changes in work characteristics and professional development in the financial sector[2]

Abstract
New technologies are changing work characteristics and professionals need to continuously adapt to these changes. This study investigates how professional development emerges from using new technologies and the associated changes in work characteristics. Eight in-depth interviews using the Critical Incident Technique were conducted with German finance professionals. The study developed and applied a theory-driven coding system for qualitative data analysis. Results indicate that different types of technologies relate to various categories of professional development either directly or through changing work characteristics. For instance, changes in external demands led to reflection on professional practices (i.e., elaboration) and information seeking (i.e., expansion), while changes in work tasks led to increased information sharing (i.e., externalization). This exploratory study provides hypotheses for future quantitative studies and suggests implications for continuing education.

5.1 Introduction

New technologies are changing work at an unprecedented scale (Brynjolfsson & McAfee, 2014; Schwab, 2017) requiring the workforce to engage in ongoing professional development to adapt to changes in professional contexts (Åström et al., 2025). While organizations have always leveraged technology for competitive advantage (Weick, 1999), recent advances are pushing the boundaries by, for instance, changing organizational value creation (Verhoef et al., 2021) or establishing mechanisms of control (e.g., Smythe, 2018). New technologies facilitate or replace the completion of employees' work tasks (Autor et al., 2003), therefore introducing new demands for work by changing the content of work tasks and the conditions for completing tasks (i.e., work characteristics) (Beer & Mulder, 2020). By engaging in professional development, employees develop the necessary competences to manage these changes while maintaining and potentially improving individual wellbeing and performance at work.
Empirical evidence on the effects of new technologies is however limited to technical implementation at an organizational level or effects on the labor market without focusing on the individual professional development required to adapt to a changing world of work (Cascio & Montealegre, 2016). Research on how new technologies are related to learning is scarce and mainly focuses on new technologies in formal learning environments (e.g., Tour et al., 2021 as an example for new skills required for teachers). Less attention has been paid

[2] The results presented in this chapter are being prepared for submission: Beer, P., & Mulder, R. H. (submitted). The Meaning of the Relationships between New Technologies, Changes in Work Characteristics and Professional Development in the Financial Sector.

to the ongoing and often informal learning and problem-solving that occurs naturally through professional practice, which is referred to as professional development. Professional development can be divided into different categories (i.e. elaboration, extension, externalization), which include specific learning activities that differ in the extent to which the individual works with new information, draws on familiar information, and the context in which the learning activities are carried out (Simons & Ruijters, 2004). The relationships between these learning activities, changes at work and new technologies is a gap in research but would allow insights into what ongoing learning at the workplace actually looks like and reveals what organizations need to do to foster and support professional development.
To fill the gap, this study explores and identifies empirical relationships between new technologies, changes at work and professional development and their meaning by investigating examples for different categories of professional development, work characteristics and new technologies.

Thus, this study addresses the following research question: How does professional development emerge from using new technologies and the associated changes in work characteristics?

This question contains three sub-questions:

1. What categories of professional development can emerge from using new technologies?
2. What kind of changes in work characteristics result from using new technologies?
3. What categories of professional development can emerge from changes in work characteristics due to new technologies?

A qualitative exploratory study was conducted in the financial sector, chosen for its high susceptibility to digitization and the lack of research on professional development (Mulder & Beer, 2020). The findings are presented below, followed by proposed hypotheses for future quantitative research and practical implications for continuing education.

5.2 Theoretical framework

Professional development emerging from using new technologies
Professional development is defined as the ongoing process of developing work-related competences (Simons & Ruijters, 2004), containing knowledge, skills, and attitudes (Ellström, 1997). It consists of three categories of learning activities: (1) Elaboration refers to learning by reviewing and evaluating experiences from practice through learning activities such as reflecting or trying new approaches; (2) Expansion refers to learning by engaging with new concepts and information through learning activities such as collecting information, seeking feedback, or assessing work role values; (3) Externalization refers to learning by developing the social context through learning activities such as sharing information, presenting ideas, or documenting knowledge (Simons & Ruijters, 2004).

Professional development can emerge from using new technologies as they represent novelty in everyday work. At an instrumental level, new technologies are defined as mechanical or digital objects that influence the completion of work tasks by complementing or replacing the process of task execution (McOmber, 1999; Autor et al., 2003). Perceiving something unfamiliar creates a disequilibrium which triggers learning activities to integrate new information into the existing cognitive model (Piaget, 1977). Technologies differ in being used either unilaterally by humans, by autonomously interacting with other technologies, or by bridging two human actors (Mulder et al., 2022). Thus, three different types of technologies are distinguished: (1) Task-supporting technologies support the manual process of executing a work task when actively used by a human actor (e.g., a calculator or an Excel spreadsheet), extending human capabilities within a rather narrow scope when humans actively use it. They change the approach to task completion by for instance introducing digital elements, prompting the individual to compare the different experiences (i.e., elaboration); (2) task-replacing technologies that replace (parts of) the process of executing a work task by itself or by interacting with other technologies without requiring human intervention (e.g., artificial intelligence or process automation), batching processes in the background after being initiated by human actors. Their unfamiliarity requires new inputs (i.e., expansion) and may require new roles, leading to explaining understandings to others (i.e., externalization); and lastly, (3) communication technologies that enable information exchange within the social context of work by functionally connecting people (e.g., video-conferencing software or project management tools for teams), enabling communication between humans (i.e., expansion, externalization). In addition, again, a comparison between past experience and the current situation takes place if the technology is regarded as sufficiently novel (i.e., elaboration).
New technologies lead to professional development by triggering employees to search for experience within one's own knowledge base (i.e., elaboration), search for new information (i.e., expansion), and share relevant information with others (i.e., externalization).

Proposition 1: Using new technologies leads to elaboration, expansion, and externalization.

Professional development emerging from changes in work characteristics due to new technologies

Introducing new technologies changes work tasks (Autor, 2013) as well as work characteristics (i.e., autonomy, complexity, workload; Hackman & Oldham, 1975). Economic research by Autor et al. (2003) showed that task-replacing technologies substitute routine tasks which leaves more non-routine tasks for employees. These non-routine tasks require the acquisition and exchange of new knowledge (i.e., expansion, externalization) requiring creativity, generalized problem-solving and communication, especially when compared to routine tasks. In addition, changes in work characteristics also trigger employees to recall previous experience to check whether the familiar ways of working are still viable (i.e., elaboration).

Proposition 2: Changes in work characteristics lead to elaboration, expansion, and externalization.

In conclusion, new technologies change work characteristics, as previous research has shown (Beer & Mulder, 2020; Fréour et al., 2021). New technologies as well as the associated changes in work characteristics trigger individuals to engage in professional development (see Figure 5).

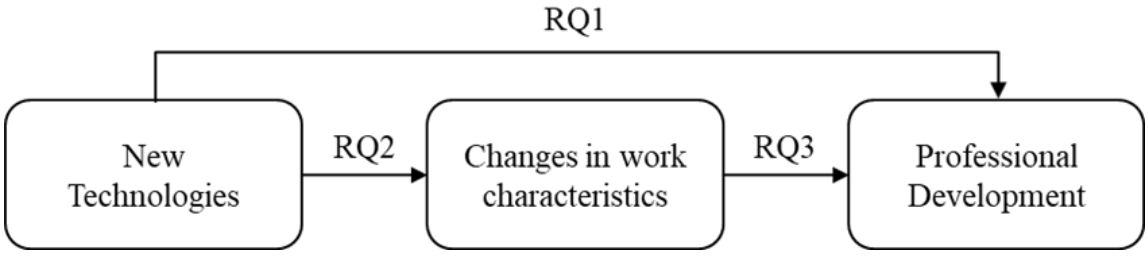

Figure 5. *Conceptual model displaying the research questions (RQ)*

5.3 Empirical Study

Design, instruments and data collection

This exploratory study employed a qualitative research design to illustrate the relationships between professional development, new technologies, and changes in work characteristics. This approach not only generates rich insights into the meaning of these relationships but also provides a foundation for the development of testable hypotheses for future quantitative research (e.g., Creswell & Clark, 2017). A semi-structured interview guideline incorporating Flanagan's (1954) Critical Incident Technique was used to investigate experiences and behavior. According to Flanagan (1954), critical incidents are observable units of action that allow for conclusions and deductions about the acting person. For the present study, participants were asked: 'Please recall the last time you were confronted with a new technology - hardware or software - that changed your work in any way.' Follow-up questions explored the new technologies, changes in work characteristics, and participants' behavior in detail. Finally, socio-demographic and occupational data were collected. The interviews (M=44.2 min, SD=16.2) were recorded via OBS, transcribed, and analyzed using MAXQDA. An ethical approval of the university's ethics committee has been obtained [ID censored for peer-review].

Sample

The financial sector was selected as a data driven domain prone to digitization while also being understudied regarding the effects of new technologies on work (e.g., Mulder & Beer, 2020) and professional development (e.g., Milligan et al., 2015).

Participants qualified for the study if they had full-time work experience in financial institutions and had completed vocational training. For work content, participants' work had to involve financial analysis and advising and/or implementing a purchase, investment, or investment decision of a client (private individual, organization), including both advisory and analytical components. Participants were recruited through a professional network established for this study through targeted outreach to financial institutions, followed by snowball sampling. This purposeful network building, starting from no prior connections in the finance sector, helped ensure a diverse and unbiased sample. The final sample consisted of eight participants that together provided detailed examples and covered technologies of all types (see Table 8 for descriptive characteristics of the sample) as well as all categories of professional development.

Table 8

Descriptive characteristics of the study participants and the conducted interviews

P	Job title	Technologies used	Professional experience (years)	Age (years)	Gender	Interview duration (min.)
1	Financial advisor, independent	Video-conferencing tool (CT)	> 30	52	Male	45
2	Wealth manager, manager	Video-conferencing tool (CT), Consulting software (TST)	26-30	44	Male	50,5
3	Risk manager	Tool for process automation (TRT)	6-10	32	Male	43,5
4	Portfolio manager	Tool for automating calculations (TRT)	6-10	38	Male	28
5	Relationship manager	Video-conferencing tool (CT), Consulting software (TST)	2-5	22	Male	33,5
6	Financial advisor, manager	Video-conferencing tool (CT)	6-10	26	Male	21,5
7	Insurance agent	Consulting software (TST)	16-20	40	Male	54,5
8	Specialist risk management	Tool for process automation (TRT)	6-10	33	Male	77

Note. P = Participant number; TRT = Task-replacing technologies; TST = Task-supporting technologies; CT = Communication technologies

Data analyses

First, a theory-driven coding system including definitions and coding rules was developed with two other researchers familiar with the topic. Definitions were based upon theoretical concepts and previous research (e.g., professional development; Simons & Ruijters, 2004), organized systematically according to the core constructs and discussed thoroughly between the researchers involved.

Building on Schreier (2014), first, a combination of deductive and inductive qualitative content analysis was conducted to test the theoretical categories' suitability for statement assignment. Second, researchers revised categories and integrated new subcategories by consensus among all researchers involved. In agreement of all four researchers involved, deductive coding worked well for new technologies (i.e., task-supporting technologies, task-replacing technologies, communication technologies) and professional development (i.e., elaboration, expansion, externalization). Inductive coding of the material proved to be necessary for coding changes in work characteristics, as the models that guided the research (e.g., Hackman & Oldham, 1975) did not fit the material. The coding started with categories from these models and was then gradually revised inductively. For instance, a theoretical subcategory of work characteristics called 'role expectations' (Beer & Mulder, 2020), which describes the expectations from others regarding one´s role, was replaced by a new subcategory called 'interaction at work' because it better reflected the codes assigned to the subcategory stressing interaction and communication (e.g., possibilities to contact others, change in occasions for exchanging information). Final inductive clustering of the changes in work characteristics resulted in four superordinate work characteristics (i.e., work comfort, work tasks, external demands, interaction at work) which will be detailed in the results section. The revised coding system was then used for the main run of the analyses (see Table 9 for an extract of the coding system).

Table 9

Examples of the descriptions for each of the three main categories.

Main Category	Subcategories	Dimension	Description
New technologies	Task-supporting technologies	Semi-active use	Specific indication that the technology acts autonomously to some capacity
		Task replacement	Specific indication that the technology replaces some or all manual process of executing a task
Changes in work characteristics	External demands (inductively derived category)	Changes in customer behavior	Specific indication that customer behavior is changing
		Changes in customer needs	Specific indication that customer demands on the output and/or quality of work is changing
Professional Development	Expansion		Specific indication of getting or searching for new information or inputs (e.g., asking for feedback, searching up information, reading)

To ensure quality, one of the researchers previously involved in the development of the coding system was invited to code the relevant statements using the revised coding system. Interrater reliability was .82 (Cohen´s $\kappa = .82$; $p < .001$) across 29 coded statements,

indicating an adequate fit between the coding system and the coded statements (Landis & Koch, 1977). Due to the satisfying fit, all instances were included in the subsequent analysis.

5.4 Results

New technologies
Participants' critical incidents involved new technologies of all types. Video-conferencing software that enables digital communication with colleagues as well as clients was classified as communication technology (P1, P2, P5, P6). Consulting software that supports counseling processes by structuring the conversation, storing client data, and checking regulatory requirements was classified as task-supporting technology (P2, P7). Tools for automating calculations enabling semi-autonomous processing of large amounts of data in a very flexible and application-specific form, and tools for process automation enabling the automation of data exchange and processing across business units were classified as task-replacing technologies (P3, P4, P8).

Professional development emerging from using new technologies
Various learning activities directly referring to the use of technology were reported (see Table 10).

Examples were found for task-supporting technologies leading to expansion in the form of participating in training (P7) and exchanging information (P2).
Further detailed examples of task-replacing technologies that led to elaboration, expansion, and externalization were found. Learning activities that reflect expansion included using knowledge resources (P3), applying inputs found online (P3) and asking experts (P4). Learning activities reflecting externalization included sharing knowledge with colleagues (P3) as well as presenting new knowledge to supervisors (P3). The learning activity reflecting elaboration was the manual step-by-step reproduction of a tool’s calculation after an error was suspected (P4).
No examples of learning activities directly referring to the use of new communication technologies were mentioned.

Changes in work characteristics resulting from new technologies
All types of technologies were reported by the subjects to have changed work characteristics (see Table 11 for the coded instances).

Task-supporting technologies decreased the effort required to complete tasks (P2, P7) and the error-proneness during consulting (P2, P7).
Task-replacing technologies made work more comfortable by decreasing the effort required at work (P3, P4, P8). Within the examples found, they reduced the error-proneness during work (P8) similar to task-supporting technologies. In addition, they changed the content of work tasks from manual tasks (e.g., updating databases) to more challenging tasks (e.g.,

working on the quality of data streams within the organization) (P3, P8). There were also examples of task-replacing technologies changing customer needs in a way in which the clients and customers demanded more technologically enhanced financial services (P3) and increased the frequency of communication about such technologies at work across different departments (P3, P8).

Table 10

Instances of professional development resulting from the use of new technologies

Specific technology	Specific learning activity	Exemplary quotes	P
Consulting software (TST)	Participating in training (EXP)	There is a wide range of courses on [how to use the tool] at the main office in [city name], where I have booked courses on a wide range of specialist topics, including one-day seminars.	7
	Exchanging information (EXP)	So, quite profanely, I can think of a situation where the tool did not deliver a result. And [the solution for that] just came to light through an exchange.	2
Tool for process automation (TRT)	Self-training using knowledge resources (EXP)	Um, well, there's quite a lot of literature on it, also a lot of hands-on literature, which, let´s say, comes more from the field of statistics than from the computer- or IT field. Um, I was able to teach myself something with that quite well.	3
	Applying new input (EXP)	So, these people, at least as I perceive it, then magically whip out the code which I then used. And threw me chunks of code and sent over whole files, like, 'I did this so and so, and try out these packages,' and so on.	3
	Sharing knowledge (EXT)	But what's funny is that a colleague of mine is doing the same seminar [on automation tools] now and of course I had a bit of an exchange with him. And I also said to him, 'Look, I've tried out this and that library, you should do it too', and so on.	3
	Presenting to leader (EXT)	Yes, but [using artificial intelligence] was also due to my boss, my team leader. He is actually even more tech-savvy than I am. And then I just showed it [to my supervisor], 'Look here, I've built a neural network in Excel'	3
Tool for automating calculations (TRT)	Comprehending results (ELA)	So [an error in calculations] has happened before, and often I have then, in principle, set [the spreadsheet] up again, in parts, to be able to understand what is actually happening now, what is supposed to happen, and what ultimately comes out of it.	4
	Asking experts (EXP)	My experience was that I basically got more input in these forums, got more answers to my questions, than in these documents on the [formal training]. […] And of course, specific problems could be dealt with directly; I asked questions and found answers.	4

Note. P = Participant the respectively illustrated learning activities; TST = task-supporting technology; TRT = Task-replacing technology; CT = communication technology; ELA = Elaboration; EXP = Expansion; EXT = Externalisation;

Table 11

Instances of changes in work characteristics resulting from the use of new technologies

Specific technology	Change in work characteristic	Exemplary quotes	P
Consulting software (TST)	Decrease in error-proneness (WT)	Whenever working with a counselling tool, the topic of data collection and data processing is at a consistently high level. Then you don't have the advisor saying 'Gee, I forgot about that.'	2,7
	Decrease in required effort (WC)	And otherwise, of course, this tool is brilliant. [...] So, if I had to do it myself, develop it myself, or if I had to link up somewhere on my own as a lone fighter, it would be incredibly expensive and an incredible effort.	2,7
Video-conferencing tool (CT)	Simplification of making contact (IN)	After all, you also have customers who don't live around the corner. And it was always very difficult to do business with them in person. Remote counselling [using video-conferencing tools] has helped a lot, because now you can also do something with them.	1,2,6,7
	Impairment of trust-building (IN)	Via the webinar tool, it's always straight to the point, um, straight to the relevant content. Nevertheless, there is a certain barrier. […] so, it is important to establish trust, and that is somehow a bit more difficult at a distance.	5,6
	Change in customer needs (ED)	So, these Skype meetings, these Webex applications and whatever they're all called, work for many customers in such a way that they say, 'Hey, then it's actually enough if we meet once or twice a year, the rest we'll do via video call or whatever'.	1
	Increase in comfort at work (WC)	Yes, because, let's say, I have personal appointments, so I travel a lot to customers in the company to hold talks. That is, of course, travelling time and commuting. So, that's rather pleasant [when using video conferencing].	1,2
Tool for process automation (TRT)	Change in occasions for exchange (IN)	So, the IT colleagues, when they said, 'Yes, Mr. 3, he's doing something with autoencoders and so on', after two weeks suddenly a group of five IT colleagues came to my office saying, 'Can we see the code? We wanted to do that too, it's funny'.	3,8
	Change in customer needs (ED)	And even when we have external consultants, for them, [automation] is now also increasingly focused on, because the customers now want more and more automation, they also found that to be quite a hot topic.	3
	Decrease in error-proneness (WT)	But I can completely rely on the fact that if the input is there, then what comes out through the computer is automatically correct. So, all these human errors that happen in these repetitive activities are completely, yes, negligible.	8
	Increase in comfort at work (WC)	But I think the work has become more pleasant, because it is precisely the redundant work that is tough. When I interact with others, for instance, that is more pleasant for me than when I copy thirty folders	3

Table 11

Instances of changes in work characteristics resulting from the use of new technologies

Specific technology	Change in work characteristic	Exemplary quotes	P
		from left to right or manually fiddle around in Excel. So, I would say that it has already become more pleasant.	
	Decrease in required effort (WC)	Because there's no longer this classic workday. Because these things that have to be done recurrently, they then take care of themselves [by automation]. They only have to be moderated and you have more time.	3,8
	Change in task content (WT)	At the beginning, I automated [my daily tasks] to such an extent that I could do the daily work in twenty minutes. And then I could use the rest of the working day to improve the conditions so that I could work properly. In other words, working on data quality and data flow.	3,8
Tool for automating calculations (TRT)	Decrease in required effort (WC)	That saves work, of course, because around this whole Python workframe [sic], I basically already have modular units that I no longer have to set up independently with Excel.	4

Note. P = Participant reporting the respectively illustrated learning activities; TST = task-supporting technology; TRT = Task-replacing technology; CT = communication technology; WC = Work comfort; IN = Interaction at work; ED = External demands; WT = Work tasks;

Communication technologies made it easier to get into contact with colleagues or clients (P1, P2, P6, P7). Simultaneously however, an impairment of trust building due to virtual communication was mentioned when talking to clients via videoconferencing (P5). Also, a change in customer behavior was noted, whereby the customers had more frequent but less intensive meetings with the employee using videoconferencing compared to meeting in person (P1), as well as an increase in work comfort due to less time needed for traveling to clients (P1, P2).

Inductive clustering resulted in four superordinate work characteristics: (1) work comfort, defined as effort exertion and the associated cognitive and emotional experience of laboriousness during task accomplishment. It includes changes in cognitive and physical demands in terms of workload and experience of pleasantness of discomfort; (2) work tasks, defined as the content of work and requirements for executing tasks effectively. It includes changes in task content and risk for errors when completing tasks; (3) external demands, defined as demands on quality of work and methods. It includes criteria for work quality and expectations of clients; and (4) interaction at work, defined as contents and opportunities for exchange with others and demands for successful interaction. It includes opportunities for exchange and for instance the appropriate tone and frequency of interaction.

Professional development emerging from changes in work characteristics

Various learning activities emerging from changes in work characteristics were reported for all types of technologies (see Table 12 for the coded instances).

Changes in external demands (e.g., clients demanding more technologically enhanced financial services) led to elaboration in the form of reflecting on one´s professional habits (P1) and expansion in the form of participation in formal training (P3).

The examples reported for changes in interaction at work (e.g., an increase in opportunities for videoconferencing) led to elaboration, again, in the form of reflecting on one´s professional habits (P1) and expansion in the form of exchanging information with a colleague and getting feedback (P2).

Instances in which changes in work tasks (e.g., from manually updating databases to working on the quality of data streams) were reported led to elaboration in the form of reflecting on one´s professional habits (P1) and developing ideas (P8) as well as one instance of externalization reflected by convincing others of a certain approach to work (P8).

No examples were found for professional development due to increases in work comfort.

Figure 6 shows the relationships between constructs, with different arrow types representing different types of technologies (see notes).

Table 12

Instances of professional development resulting from changes in work characteristics due to new technologies

Change in work characteristic	Specific learning activity	Exemplary quotes	P
Change in customer needs (ED)	Reflecting (ELA)	Well, you're a person of habits. And I've noticed [while transitioning to remote consulting] that my habits are no longer up-to-date or necessary. So desperately driving somewhere quickly, thinking 'Hopefully I'll make it there on time to the customer at 10 o'clock'.	1
	Participating in training (EXP)	Yes, and then I took part in the further training [on data science], which was when I reached the peak, so to speak. Then you had another six months or three quarters of a year where you focused strongly on that.	3
Simplification of making contact (IN)	Reflecting (ELA)	[Using the communication tool] I then had to constantly question myself 'Is [this meeting] still an added value now, or is it just too much?'	2
	Exchanging information (EXP)	From my point of view, it is always good to look for a corrective entity, and I always exchange ideas with a colleague who has a similar situation, having the same management scope, the same area of responsibility. How he handles it.	2
	Obtaining feedback from the team (EXP)	And it's also the case that my people give me feedback and say, 'Gee, it's really getting a bit much now [digital communication]'. So that would also be the case if I were to overdo it. So I also ask my people.	2
Change in task content (WT)	Reflecting (ELA)	And [due to the effects of automation], I just took a step back and asked myself, 'Does this even make sense, what I'm working on right now?' And 'Is this right?'	8
	Convincing others (EXT)	And then I first tell [the colleagues from other departments] what I do and try to find out what they do. And then I explain what I'm planning. I try to establish a common basis to create a sense of 'Look, I have this and that in mind, that would be quite interesting for you. It's good for you, it's good for me, let's work together, it's good for all of us'.	8
Decrease in error-proneness (WT)	Developing ideas (ELA)	And then my head is also free for content-related things, then I come up with good ideas much faster to develop substantive ideas.	8

Note. S = Participant reporting the respectively illustrated learning activities; ELA = Elaboration; EXP = Expansion; EXT = Externalization; IN = Interaction at work; ED = External demands; WT = Work tasks;

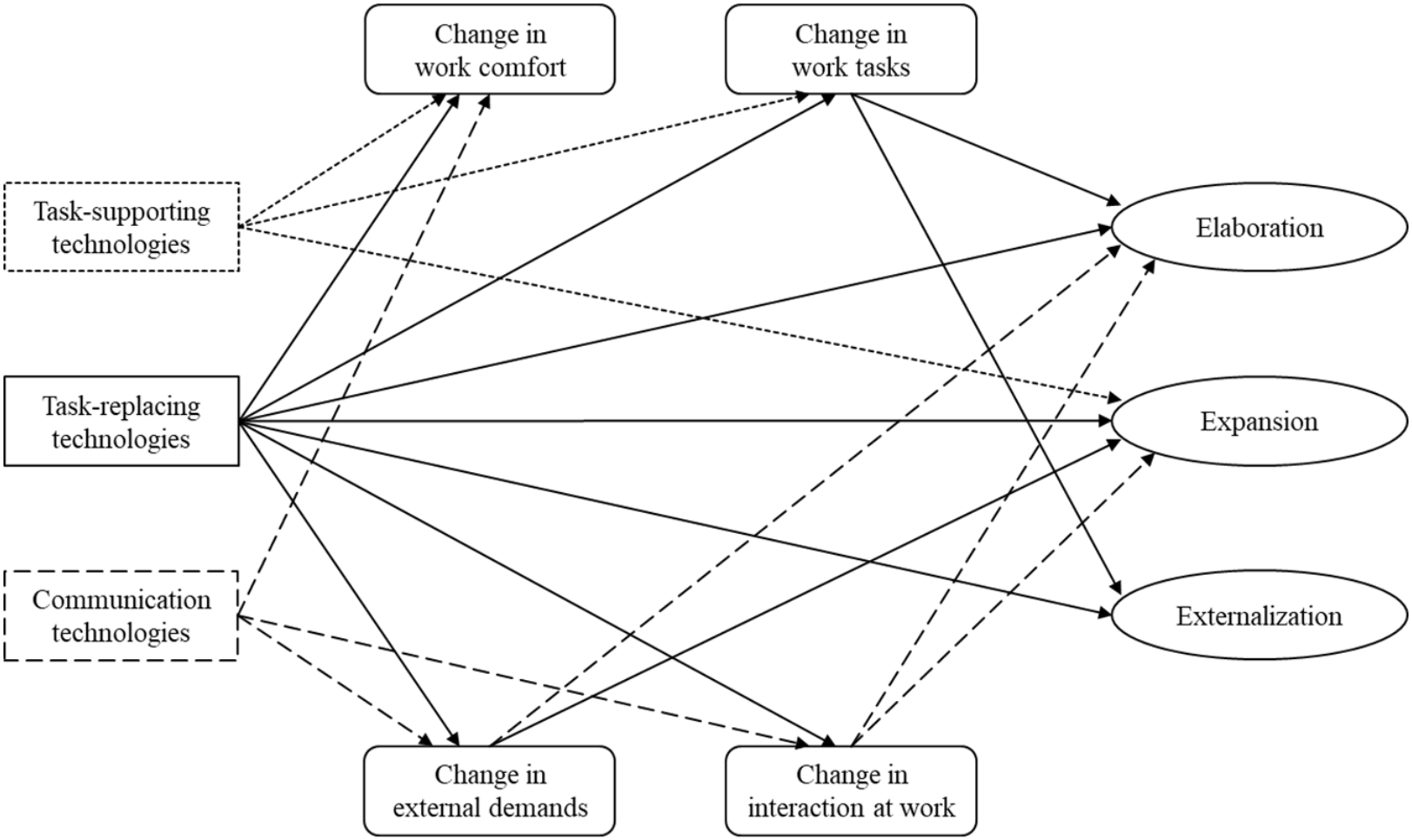

Figure 6. *Visualisation of the identified relationships between different types of new technologies, changes of work characteristics and categories of professional development. Arrows represent a directional relationship between constructs. Dotted lines depict the effects of task-supporting technologies, continuous lines depict the effects of task-replacing technologies, and dashed lines depict the effects of communication technologies.*

5.5 Discussion

The present exploratory interview study aimed to identify relationships between new technologies, changes at work and professional development and their meaning. Results of deductive and inductive coding of the data after interviewing eight finance professionals using a semi-structured interview guideline revealed that different types of new technologies were linked to all categories of professional development (i.e., elaboration, expansion, externalization) directly or by means of changing different work characteristics.

Using new technologies causes professional development

Addressing RQ1, learning activities directly referring to task-supporting and task-replacing technologies were identified. These mainly involved expansion, with some examples including externalization and elaboration when using task-replacing technologies. Communication technologies were not linked to any form of professional development.

Task-replacing and task-supporting technologies drive expansion as employees seek to understand them. Related research showed that working with new technologies sharpens roles (Parker & Boeing, 2023), which we found evidence for in the present study. Engaging with new technologies can increase knowledge about the technologies themselves, potentially improving workplace usage and attitudes towards new technologies (e.g., Gennaro et al., 2022).

Hypothesis 1: Using task-supporting technologies and using task-replacing technologies leads to expansion.

Elaboration occurred when employees comprehended results from task-replacing technologies. Employees engage in elaboration when experience is sufficient (e.g., Meylani, 2024). Elaboration could be prevalent whenever employees draw from experiences first rather than seeking external input. This may explain the absence of professional development from communication technologies. While these facilitate relational job crafting (Gennaro et al., 2022), they may not trigger professional development in finance due to familiarity and rarely require updating knowledge or skills.

Hypothesis 2: Using new communication technologies leads to elaboration, expansion, and externalization when the familiar and the new technologies differ significantly.

No evidence linked task-supporting technologies with elaboration. Since these technologies were predominantly linked to expansion, employees appeared to prefer seeking new information over reviewing existing experience. The results suggest different nuances for Proposition 1, as different types of technologies relate to various categories of professional development.

Using new technologies causes professional development through changes in work characteristics

Addressing RQ2, changes in work comfort, work tasks, interaction at work and external demands were reported across technologies. Work comfort increased with all types of new technologies. Work tasks changed due to task-replacing and task-supporting technologies. Communication and task-replacing technologies led to changes in external demands and interaction at work by increasing interaction opportunities and frequency. This study advances domain-specific examination of work characteristics (e.g., Parent-Rocheleau & Parker, 2022), as for instance changes in external demands are particularly relevant in jobs with a service component, as is finance. Identifying domain-specific work characteristics also extends models such as Hackman and Oldham (1975), which may not always fit due to the broad categorization, as was the case in this study.

Addressing RQ3, changes in external demands, interaction, and work tasks led to all categories of professional development. Technologies improved work comfort by making tasks more pleasant and less exhausting (e.g., Zuboff, 1988). While Perez, Conway, and Roques (2022) found task-replacing technologies created mundane tasks, our study emphasized their usefulness in replacing such tasks. However, increased work comfort did not trigger professional development. Notably, in all reported instances where a change in work comfort was mentioned, work comfort increased. Work comfort can be viewed as a psychological resource (Hobfoll, 1989). Whether a decrease in work comfort leads to professional development needs further investigation.

Hypothesis 3: Increasing work comfort due to using new technologies does not lead to elaboration, expansion, or externalization.

Communication technologies changed work interactions, offering remote client advising benefits while presenting trust-building challenges. Task-replacing technologies sparked interdisciplinary exchanges, aligning with findings that such technologies foster relational crafting across stakeholder groups (Perez et al., 2022) and supporting the idea, that novelty motivates engagement through exchanges with others. Regarding changes in work characteristics, communication technologies increased communication at work. This is beneficial in the case of for instance expanded client reach, but previous research around technostress also poses challenges when communication gets easier (Ayyagari et al., 2011). In any case, communication technologies led to elaboration and expansion only when employees recognized changes in communication and interaction.

Hypothesis 4: Increasing interaction at work mediates the positive relationship between using communication technologies with elaboration and expansion.

Communication and task-replacing technologies changed customer needs and service quality demands. Changes in external demands consistently triggered professional development, due to high client orientation in finance correlating with job performance and satisfaction (e.g., Gil Saura et al., 2005). Changes in customer demands could thus drive

employees to engage in professional development to maintain performance. With communication technologies, changes in external demands affected consultation frequency and type, suggesting technology use in service-focused domains is a specific aspect of professionalism. Similarly, with task-replacing technologies, automation and AI were increasingly demanded by institutions and customers for competitiveness and innovation.

Hypothesis 5: Changes in external demands mediate the positive relationship between using communication technologies with elaboration.

Hypothesis 6: Changes in external demands mediate the positive relationship between using task-replacing technologies with expansion.

Task-supporting and task-replacing technologies changed work task content and characteristics. Task changes triggered examination of experience (i.e., elaboration), aligning with evidence that the standardization of work procedures due to artificial intelligence resulted in task crafting behavior (Perez et al., 2022). Externalization was a by-product of the new task content which requires positioning oneself within the social context.

Hypothesis 7: Changes in work tasks mediate the positive relationships between using task-replacing technologies with elaboration and externalization.

Comparing professional development directly caused by new technologies versus changes in work characteristics suggests another hypothesis: While expansion is prevalent in the first case, elaboration may be the dominant form for the latter. Specific changes (i.e., a new tool that can be used) might lead to more intentional learning (e.g., actively searching for information, which would be expansion), while subtle changes in work characteristics may lead to more incidental learning (e.g., reflecting, which would be elaboration).
Hypothesis 8: Changes in work characteristics are stronger related to elaboration than to expansion and externalization.

In sum, the results raise different nuances for Proposition 2, in that changes in different work characteristics seem to be related to different categories of professional development to various degrees.

Limitations

The relatively small sample size and the focus on German financial institutions can be considered limitations. Despite potential selection bias due to the sampling strategy chosen, the final sample achieved sufficient diversity to represent the research phenomenon while maintaining thematic coherence. In addition, illustrative examples were identified for all types of new technologies and all categories of professional development. This illustration is not exhaustive in accordance with the primary objective of this exploratory study. This study sought to explore the relationships and their meaning, laying groundwork for future quantitative testing. Therefore, hypotheses were derived that can guide future research to test

the relationships between the core constructs. This methodological progression from qualitative exploration to quantitative testing represents a robust approach in this emerging field of research.

The focus on the financial sector could be considered a limitation. The technologies used in other professions differ and it is possible that the effects of these technologies are equally diverse. The results could however extend to domains that are similarly knowledge-intensive (i.e., the characteristics of the profession) and in which technologies are implemented for compliance with regulatory practices (e.g., characteristics of the technologies). This could apply to similar domains, such as controlling, but also to for instance medicine and healthcare. Future research should examine technology use and professional development across different domains.

Practical implications

Firstly, professionals and especially leaders need to manage their own professional development, embrace change, and craft their own work whenever the emergence of new technologies makes this possible or even required (e.g., Wrzesniewski & Dutton, 2001). Our research revealed that seeking out new information and knowledge (i.e., expansion) was especially visible when using task-replacing technologies, stressing the need for organizations to provide appropriate knowledge resources. This can be achieved by explicitly using, creating and organizing opportunities to exchange work experiences. By providing resources, organizations can enhance the odds for Communities of Practice (Wenger, 1998) to be naturally formed around new technologies. As shown in this study, new technologies have the potential to promote interdisciplinary and interdepartmental exchange. However, realizing such opportunities requires a certain readiness for change and organizational awareness is needed for everyone to take advantage of the opportunity spaces created by the change.

Secondly, being aware and raising awareness regarding the effects these technologies have on work and professional development is essential. Our research demonstrates that communication technologies changed work characteristics, introducing new tasks and roles. Awareness therefore should not only be limited to understanding the direct impact of new technologies (as stressed above) but recognizing the broader changes in work characteristics. This perspective aligns with innovation development research as disrupting established routines leads to innovations (Nelson & Winter, 1982). This is particularly important when introducing technologies that seem rather familiar (as for instance contemporary communication technologies) but change work characteristics in a way that could not have been foreseen by organizations.

Finally, the exploration of new ideas and opportunities by employees may not be immediately visible to colleagues or managers. Adapting to changing working characteristics because of new technologies may happen subtly while creating additional tasks that are not visible to leaders or the organization, thus being detrimental to employee wellbeing and performance. When using task-supporting and communication technologies, reflecting on one's own routines and approach to work (i.e. elaboration) happens rather covertly. In addition, and as soon as the invisible tasks have been made visible, changing

roles, especially through using task-replacing technologies, can make it necessary to communicate these changes to others (i.e. externalization). Organizations can strategically leverage awareness of these hidden dimensions of implementing new technologies by fostering organizational development through the facilitation of knowledge externalization and retention (Aroles et al., 2023).

In conclusion, new technologies and the associated changes in work characteristics require professionals to manage their own professional development with organizational knowledge support, fostering awareness of how new technologies change work characteristics; and recognizing the hidden processes that require communication in order to enhance wellbeing and performance while advancing organizational goals.

6 Study 3: The relationships between professional development, new technologies and changes in work characteristics: a survey study in the financial sector[3]

Abstract
Professional development may be essential for sustaining employee health and commitment as new technologies transform work, yet these links remain unclear. This study explores the impact of task-supporting, task-replacing, and communication technologies on changes in work characteristics and professional development – which consists of the different aspects elaboration, expansion, and externalisation. The research question is: How do different types of new technologies impact work characteristics and professional development, and how do changes in work characteristics relate to professional development and its associated work outcomes?
A cross-sectional survey of 95 finance professionals tested hypotheses regarding differences in professional development and changes in work characteristics across types of new technologies and relationships with work outcomes such as job satisfaction, emotional exhaustion, and organisational commitment. Results show that task-replacing technologies are associated with expansion, communication technologies with externalisation, and task-supporting technologies with elaboration. Significant differences were observed in both the intensity and direction of changes in work characteristics, such as the quality of communication, across types of technologies. Changes in work characteristics, for instance in workload, were positively related to professional development, though these relationships varied depending on the types of new technologies. Relationships between professional development and organisational commitment were established. Additionally, individual characteristics such as occupational self-efficacy and technological acceptance were linked to professional development.
These findings inform the need for more targeted and context-sensitive HRD strategies and underscore the importance of further longitudinal research to understand the dynamic interplay between technology, work, learning at work, and its outcomes in evolving organisational contexts.

6.1 Introduction

In today's rapidly evolving work environments, driven by the proliferation of digital tools, process automation, and artificial intelligence, the demands placed upon employees are undergoing fundamental changes, especially in financial institutions (Parker & Grote, 2022; Donald et al., 2023; Verhoef, 2021). Finance organisations across sectors are increasingly

[3] The results presented in this chapter are currently being prepared for submission: Beer, P., & Mulder, R. H. (in progress). The Relationships between Professional Development, New Technologies and Changes in Work Characteristics: A Survey Study in the Financial Sector.

adopting new technologies – defined as digital or mechanical tools that complement or replace task completion (McOmber, 1999; Autor et al., 2003) – to enhance efficiency, improve service delivery, and remain competitive in global markets (Abbas et al., 2024). While these innovations promise increased productivity for the organisation, they also introduce new challenges for the individual by impacting work outcomes, such as organisational commitment, job satisfaction, and employee well-being (Theorell, 2020; Alves et al., 2024). A review of the literature (Mulder & Beer, 2020) has shown that the introduction of new technologies can directly influence work outcomes, highlighting the need for Human Resource Development (HRD) to effectively manage these outcomes, given their associations with turnover intention (Nketsiah & Nkansah, 2024), psychological well-being (Matud et al., 2024), and burnout (Anbar & Eker, 2008). One way of achieving this is by facilitating professional development, defined as an employee's ongoing development of competences required for accomplishing work (Simons & Ruijters, 2004). For instance, emotional exhaustion, defined as feeling emotionally overwhelmed and depleted by work (Maslach et al., 1997), may be mitigated by professional development through fostering competences that help employees cope with anxiety regarding organisational change. Job satisfaction, defined as the perceived satisfaction with various job aspects (Pejtersen et al., 2010), may be enhanced by engaging in professional development, as these activities likely increase experiences of competence and autonomy, thereby supporting self-determination (Ryan & Deci, 2020). And organisational commitment, defined as the attitude influencing employees' decision to maintain organisational membership (Allen & Meyer, 1996), may strengthen through professional development, as investing extra-role effort can deepen employees' felt connection with their organisation (Lee et al., 2019; Wulan et al., 2024).

In addition to supporting mental and physical health, enabling employees to meet job demands, and enhancing job satisfaction and self-efficacy (Pargmann et al., 2023), engaging in professional development helps individuals adapt to change and new situations. This adaptability becomes especially important as work environments grow increasingly dynamic due to the introduction of new technologies (Donald et al., 2023; Otoo, 2019). New technologies change work characteristics, such as workload, autonomy, or specific task demands (Beer & Mulder, 2020). Initial research has identified differences between various types of new technologies, including those that replace parts of task completion (i.e., task-replacing technologies), those that complement task completion (i.e., task-supporting technologies), and those that enable communication (i.e., communication technologies) (Bornhaupt & Mulder, 2025; Beer & Mulder, submitted), but there is no definitive system for determining which work characteristics are changed by what technologies. A systematic understanding of changes in work characteristics is needed in order to better predict how employees respond through engagement in professional development, as these changes may represent the crucial link between new technologies and professional development.

This study seeks to address this need by investigating the relationships between new technologies and professional development, with a particular focus on changes in work characteristics resulting from new technologies. In addition, individual characteristics that

may play a role in these relationships are explored, with particular attention to technological acceptance and occupational self-efficacy. The research question is: How do different types of new technologies impact work characteristics and professional development, and how do changes in work characteristics relate to professional development and its associated work outcomes?

This question consists of five sub-questions:

1. Do the aspects of professional development vary according to the type of new technologies used?
2. How do changes in work characteristics vary across different types of new technologies?
3. What are the relationships between changes in work characteristics and professional development?
4. What are work outcomes of engaging in professional development?
5. What individual characteristics are related to professional development?

To answer these questions, a cross-sectional survey study targeting finance professionals in Germany was conducted. The financial sector, characterised by rapid technological change driven by regulatory demands, the need for complex decision-making, and an increasing need for digital literacy, offers a highly relevant context for examining how employees respond to change through engaging in professional development.

6.2 Theoretical framework

New technologies and professional development

Professional development refers to an ongoing process of developing one's own competences (e.g., Ellström, 1997). Simons & Ruijters (2004) distinguish three core aspects of professional development: elaboration, which involves reflecting on and reinterpreting one´s own prior experiences; expansion, which entails acquiring new information, new knowledge and perspectives; and externalisation, which concerns the articulation and sharing of information with others. New technologies are conceptualised as mechanical or digital tools or systems that influence the execution of work tasks either by complementing or replacing human efforts (McOmber, 1999; Autor et al., 2003). Different types of technologies, depending on their functionalities regarding the work tasks that need to be accomplished, may prompt employees to engage in various aspects of professional development by introducing cognitive conflicts, or experiences of "disequilibrium," that require processes of equilibration to resolve (Piaget, 1967). According to Piaget's (1977) theory of cognitive development, such disequilibrium occurs when individuals encounter situations that cannot be assimilated into their existing cognitive schemas, thereby prompting learning processes aimed at restoring equilibrium through either the assimilation of new information or the accommodation of existing cognitive structures. In this context, three types of new technologies can be identified in the literature, each of which may be linked to

distinct aspects of professional development by virtue of the specific cognitive conflicts they introduce:

Task-supporting technologies assist individuals in performing tasks while being actively used and without displacing human agency, such as software for data entry or decision support (Beer & Mulder, submitted). These technologies are closely tied to established work processes. Even if they change the way tasks are performed, for instance, by digitising a previously manual process, the necessary learning involved in using these tools draws primarily from prior knowledge of the manual process and how it is done. When a task-supporting technology introduces digital elements to an activity previously performed manually, it creates a cognitive conflict as employees must reconcile the new digital process with established routines. This process prompts employees to compare both experiences, drawing on past knowledge to refine and adapt existing work routines, which primarily leads to elaboration (Simons & Ruijters, 2004). Thus, elaboration is likely to be the most prominent aspect of professional development when dealing with task-supporting technologies.

H1a: Elaboration is higher when using task-supporting technologies compared to other types of new technologies.

Task-replacing technologies autonomously execute (parts of) work processes, such as robotic process automation or elements of artificial intelligence, thereby reducing the direct involvement of human action (Beer & Mulder, 2020). This aligns with current technological development, where such technologies are increasingly disruptive by being capable of automation (Villar & Khan, 2021). When a task-replacing technology automates parts of a process to task completion, it introduces a cognitive conflict, as employees must adapt to either fundamentally changed workflows or entirely new tasks and responsibilities. In order to resolve this disequilibrium, employees may find themselves needing to acquire new conceptual and procedural knowledge not only about the altered workflow, but also about the technology responsible for these changes. This prompts employees to engage in expansion (Simons & Ruijters, 2004), as they actively seek and acquire new information. Thus, expansion is likely to be most prominent when dealing with task-replacing technologies.

H1b: Expansion is higher when using task-replacing technologies compared to other types of new technologies.

Communication technologies facilitate interaction between individuals or teams, for instance tools for videoconferencing, messaging, and collaborative project management (Beer & Mulder, submitted). They are used by employees exclusively to communicate with others at work, whether internally with colleagues, managers, or other departments, or externally with clients. When a communication technology enables communication in both frequency and quality, it may introduce a cognitive conflict, as employees encounter new forms of,

opportunities for and demands for articulation and collaboration. To restore equilibrium, employees may be more inclined to articulate their knowledge and engage in collaborative problem solving due to the immediate availability of others at the push of a button. As these technologies are often familiar from private contexts, the associated learning activities are less about understanding the technology itself and more about sharing and externalising information. This prompts employees to engage in externalisation as it is most closely related to employees' need for sharing information. Thus, externalisation is likely to be most prominent when dealing with communication technologies.

H1c: Externalisation is higher when using communication technologies compared to other types of new technologies.

New technologies and changes in work characteristics

The effects of new technologies on work characteristics can be interpreted through models such as the Job Demand-Control (JDC) model (Karasek, 1979), which posits that strain occurs when high demands are combined with low control, and the Job Demands-Resources (JD-R) model (Demerouti et al., 2001), which categorises work characteristics as either demands (e.g., workload, ambiguity) or resources (e.g., autonomy, support). By using these frameworks in empirical studies, valuable insights have been gained into how different features of work influence psychological outcomes such as motivation (e.g., Job Characteristics Model, JCM; Hackman & Oldham, 1975). As new technologies have been shown to affect a wide range of work characteristics in various ways (Beer & Mulder, 2020), there is still a lack of rationale for predicting the specific types of changes in work characteristics, particularly regarding professional development. Therefore, it is hypothesised that there will be differences in the types of work characteristics affected. More specifically, the types of new technologies introduced into the workplace are expected to affect the changes in work characteristics, in terms of how intense the change is, and in terms of the direction in which it is perceived to move (Mulder et al., in progress). Initial qualitative research has shown that for instance, task-replacing technologies may lead to changes in work roles or perceived autonomy compared to task-supporting technologies, while communication technologies may disrupt established patterns of collaboration and responsiveness in more intense ways than the other types tend to (Beer & Mulder, submitted). Accordingly, we formulate the following two hypotheses:

H2a: The intensity of changes in work characteristics differs across the types of new technologies.

H2b: The direction of changes in work characteristics differs across the types of new technologies.

In addition to the type of technology itself, the perceived changes in work characteristics have been shown to affect professional development (Bornhaupt & Mulder, 2025). When such changes are experienced as disruptive, ambiguous, or difficult to interpret within

existing schemas (Bourgeois, 2012), they are likely to elicit engagement in learning activities. However, a limitation of established models such as the JCM or the JD-R model is their reliance on stable categorical appraisals: they assume that either employees experience changes as either positive or negative, as either demands or resources, and that research is valid to assume these categories (Bakker et al., 2023). This study proposes a shift in focus away from these categories by focusing on change itself (e.g., Mulder et al., in progress). Specifically, it is argued again in line with Piaget's (1967, 1977) theory of cognitive disequilibrium that the experience of change itself, irrespective of whether it is initially appraised as beneficial or detrimental, can serve as a stimulus for adaptation and development. When applied to the workplace, this perspective suggests that noticeable changes in work characteristics prompt a state of disequilibrium, which activates a search for stability and meaning, irrespective of the perceived or expected valence of the change. The focus on professional development enables the consideration of theoretically opposing effects such as an increase or decrease in the so-called resources or demands of the JD-R model. For instance, "positive" changes – such as an increase in a resource in terms of the JD-R model – may produce proactive behaviours while seemingly "negative" ones – such as a decrease in a resource in terms of the JD-R model – may stimulate problem solving or the consolidation of individual resources (cf. conservation of resources theory; Hobfoll et al., 2018); so both would lead to professional development in a way. The same however can apply to a demand, where an increase may lead to problem solving behaviour to compensate for a lack of resources, while a decrease may set free resources to engage in developmental activities beyond the typical role of an employee.

From this perspective, professional development is not driven exclusively by the type of technology or by structural work characteristics in isolation, but rather by the subjective experience of change that arises from the interaction between the two. Given the assumption on change per se as a trigger for employees to engage in professional development and the large number of potential configurations involving different types of technologies, changes in work characteristics, and aspects of professional development, this study primarily aims to identify relationships and emerging patterns:

H3a: Intensity of changes in work characteristics is related to all aspects of professional development.

H3b: Direction of changes in work characteristics is related to all aspects of professional development.

Outcomes of professional development

Beyond the development of competences, professional development plays a central role in shaping broader work-related outcomes (Simons & Ruijters, 2004). Individual level outcomes such as job satisfaction, emotional exhaustion, and organisational commitment are well established as core dimensions of employee well-being and long-term organisational sustainability (Quader, 2024).

Professional development may serve as a buffer in times of organisational change, supporting employees' sense of competence, control, and connectedness as they navigate uncertainty. Specifically, solving practical problems in action that validate existing competences and experiences (i.e., elaboration), as prompted by task-supporting technologies, or actively seeking new conceptual and procedural knowledge (i.e., expansion) in response to task-replacing technologies, should enhance employees' perceptions of effectiveness and autonomy in their roles. According to Self-Determination Theory (Ryan & Deci, 2020), enhanced feelings of competence and autonomy are fundamental for the development of intrinsic motivation and job satisfaction. This theoretical rationale is empirically supported, as higher levels of autonomy and competence have repeatedly been shown to foster overall job satisfaction (Gagné & Deci, 2005; Slemp et al., 2018). Therefore, all aspects of professional development, elaboration, expansion, and externalisation, are expected to positively relate to job satisfaction.

H4: All aspects of professional development are positively related to job satisfaction.

Moreover, the experience of competence and accomplishment associated with elaboration and expansion can also be expected to mitigate emotional exhaustion, defined as feeling emotionally overwhelmed and depleted by work (Maslach et al., 1997). Previous research demonstrates that psychological resources such as perceived competence and autonomy help employees to cope with work-related stress and reduce burnout symptoms (Gillison et al., 2019). In addition, externalisation through expressing and sharing knowledge may foster increased feelings of connectedness and social support, counteracting isolation, especially when work demands shift due to new technologies. Given that isolation and lack of support are critical risk factors for burnout and emotional exhaustion (Maslach et al., 1997; Fernet et al., 2013), it is assumed that engagement in all aspects of professional development helps alleviate emotional exhaustion.

H5: All aspects of professional development are negatively related to emotional exhaustion.

Furthermore, ongoing continuing professional development may promote organisational commitment, defined as an attitude that characterises the employee's relationship with the organisation (Allen & Meyer, 1996). Organisational commitment can be divided into three subcomponents: Affective commitment refers to the emotional attachment an employee feels towards the organisation, normative commitment describes feelings of obligation towards the organisation, and continuance commitment reflects the advantages and reasons to stay in the organisation. Investing effort in professional development represents extra-role behaviour and signals that employees are committed beyond the requirements of their formal job descriptions. As such, continuous learning activities can reinforce employees' emotional attachment and obligation towards their organisation, as previous empirical studies have indicated (Lee et al., 2019; Wulan et al., 2024). Additionally, professional development typically involves supportive organisational contexts, including time allocation, autonomy, and appreciation by leadership (Hassi, 2019). These contextual resources strengthen

employees' sense of belonging and their perception of being valued, further bolstering affective and normative commitment due to the opportunities to develop a sense of accomplishment and to reduce stress (Weinstein & Ryan, 2011). Moreover, continuous participation in professional development may increase employees' perception of accumulated organisational investments and benefits, thereby also enhancing continuance commitment. Consequently, all aspects of professional development are expected to positively relate to organisational commitment and its subcomponents.

H6a: All aspects of professional development are positively related to affective commitment.

H6b: All aspects of professional development are positively related to normative commitment.

H6c: All aspects of professional development are positively related to continuance commitment.

Finally, two individual characteristics may play a significant role in how employees engage in professional development within changing work environments. These characteristics could ultimately act as moderators, influencing the strength of specific relationships in the broader model, it is first important to explore whether and how they are associated with professional development. Establishing these direct associations provides an empirical foundation for future research on possible moderating effects:

Occupational self-efficacy, defined as individuals' belief in their capability to develop perspectives and remain persistent in the face of work-related challenges (Yoon et al., 2018), may moderate the relationship between changes in work characteristics and professional development. Individuals with higher self-efficacy typically interpret workplace changes as opportunities rather than threats, allowing them to proactively acquire new skills and knowledge (Xanthopoulou et al., 2007; Cetin & Askun, 2018). For this reason, it is assumed that occupational self-efficacy will be positively related to engagement in all aspects of professional development.

H7: All aspects of professional development are positively related to occupational self-efficacy.

Finally, technological acceptance includes aspects of self-efficacy related to technology use but also incorporates additional dimensions such as perceived usefulness, ease of use, anxiety, and cognitive and affective attitudes towards technology (Straub, 2009; Venkatesh et al., 2003). As technologies have the potential to prompt employees to engage in professional development, it is assumed that technological acceptance may moderate the relationship between the use of new technologies and professional development. A positive attitude towards new technologies and lower levels of anxiety are likely to encourage

employees to embrace innovations and participate more actively in professional development activities involving technology (Davis, 1989; Pan, 2020; Arpaci et al., 2020). Before investigating any potential moderating role of technological acceptance, it is necessary to examine its direct relationship with professional development.

H8: All aspects of professional development are positively related to technological acceptance.

The research model below presents an overview of the hypotheses (Figure 7).

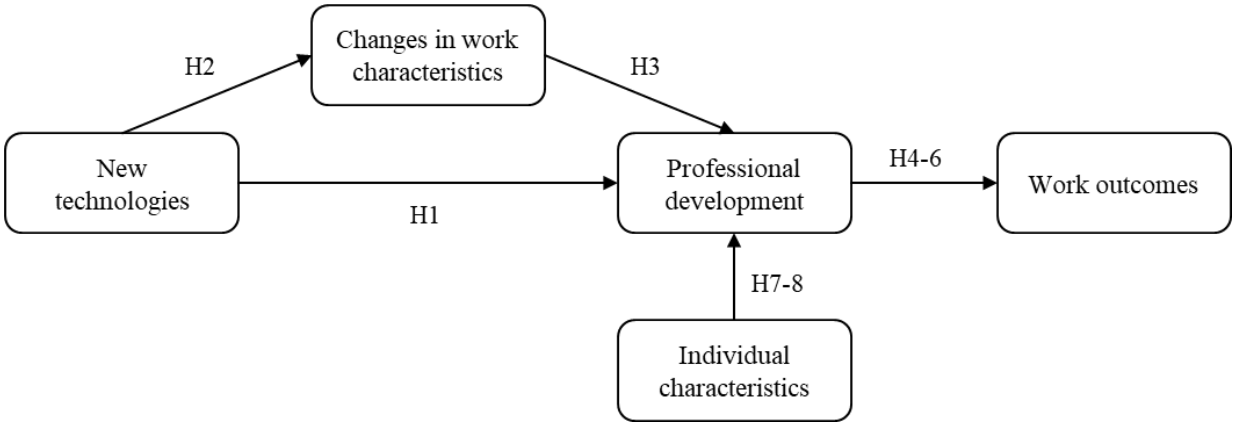

Figure 7. *Research model summarising the hypotheses*

6.3 Empirical Study

Study design and data collection

This study employed a cross-sectional survey design. A professional sector highly susceptible to digitisation was selected based on the recent presence of all types of new technologies as an eligibility criterion. The financial sector meets these requirements as it is prone to digitisation due to its focus on numerical data, financial indicators, and regulatory compliance.

Furthermore, finance professionals – such as wealth and portfolio managers, private and corporate client advisors, relationship or key account managers, risk managers, or (investment) bankers – are all consultancy-oriented and involve extensive communication with colleagues, other departments, and clients, supported by communication technologies. This communicative nature, combined with regulatory demands, means that new technological tools are frequently introduced in this sector. These include not only task-supporting technologies, for instance introduced as software to check regulatory requirements but also applications such as artificial intelligence and robotic process automation, both of which serve as examples of task-replacing technologies (see Gomber et al., 2017).

Various financial institutions and centres for financial services research, primarily located in southern Germany, were contacted and invited to participate in an online survey. Invitations were sent to interested financial institutions and centres with networks of professionals active in the area. When institutions agreed to distribute the survey, they were provided with an introduction for participants and the survey link. The survey was designed and implemented using the university's survey tool ("Sosci Survey") to ensure compliance with German data protection regulations, including local data storage. The survey was open from October 2024 to March 2025 and reminders were issued in early February 2025 and March 2025. Ethical approval was granted by the university's ethics committee before the study began (ID 24-3788-101).

Sample

Final sample characteristics can be found in Table 13 and a list of technologies in Table 14.

Table 13

Sample characteristics (N=95)

Variable	Description / Statistic
Jobs	Portfolio Manager (n = 16) Analyst (n = 15) Business Analyst (n = 10) Key Account Manager (n = 8) Bank Clerks (n = 5) Customer / Corporate-client / Private-client Advisers (n = 8) Banker (n = 14) Compliance / Risk Manager (n = 4) Back Office (n = 6) Consultants (Financial Controlling, Corporate Finance, Consulting; n = 3) Other single entries (Data Scientist, Developer, Private Banking, Private Equity, Start-up Advisory, Compliance Project Lead)
Weekly working hours	M = 36.8 hrs (SD = 6.3)
Age	M = 34.1 years (SD = 6.2)
Gender	Male = 53; Female = 42

Instrument

All constructs were measured using validated or theoretically grounded multi-item or single-item rating scales. Where applicable, items were adapted to reflect the context of the financial sector.

At the start of the survey, the type of new technologies used was measured using a three-item framework based on Mulder et al. (2022). Each item reflected a different type of technology relevant to finance professionals: task-supporting technologies, task-replacing technologies, and communication technologies. Participants indicated whether each type of

technology was applicable to their work. An example item for task-supporting technologies is: "The technology complements my work by supporting me when I actively use it (for instance advisory support software, financial planning or documentation tools)." As each technology type was measured with a single item, internal consistency metrics were not applicable.

Changes in work characteristics as a result of new technologies were measured using 14 single items derived from Beer and Mulder (2020) and Beer and Mulder (submitted). Each item represented a distinct work characteristic, such as autonomy, workload, quality of interaction, or external demands. Participants indicated the perceived change in each characteristic on a bipolar 7-point scale ranging from -3 (strongly decreased) to +3 (strongly increased).

Table 14
Specific technologies and type according to participants

Type / Group	Technologies mentioned	N
Task-replacing technologies	RPA / RPA services (robotic process automation)	20
	Microsoft 365 incl. & Copilot	
	Copilot (stand-alone)	
	ChatGPT / GenAI; AI (artificial intelligence)	
	ChatGPT + Copilot + Perplexity	
	ThinkPad	
Task-supporting technologies	Apple Vision Pro	31
	Curved monitors	
	Specialised software packages (Key-Account-Management software; Learning-Management software; Portfolio-Management software; ESG software; Performance-Management software; Embedded-Finance software; Payment software; Advisory software; Delivery software; Relationship-management software; Client-management software; Transaction/execution software)	
	SAP	
	“databases”	
	Internal “new software”	
Communication technologies	Video-conferencing software (Teams / MS Office / Microsoft 365; Zoom; Webex)	24
	Smartphone	
	Blockchain-enabled platforms	
	Success Factors	
No-new technologies	No mentions	21

Example items include: "The time it takes me to complete my work has..." (workload), "The quality of communication with colleagues has..." (quality of communication), and "The demands from clients regarding my work have..." (external demands). A direct reference to the new technology was always made within the instruction of these measures. The survey strongly emphasised that the changes in work characteristics referred to the period since the

introduction of the new technology, which the participant had selected at the beginning of the survey. If a participant was unable to identify a new technology introduced within the last three months with which they had direct contact, they were still asked questions about changes in work characteristics, but without this direct reference. In this case, they were asked whether any of the work characteristics had changed in the past three months and were presented with the same set of items. This would allow for analyses not only of groups using the different types of technologies but a group of employees without any new technology introduction.
Table 15 shows an overview of the work characteristics included in this study and their respective measurements.

Professional development was measured with 24 items developed based on the framework by Simons and Ruijters (2004) consisting of three aspects: elaboration, expansion, and externalisation. Each aspect was assessed with 8 items. The items capture actual learning activities. Each of the three aspects included an equal balance of certain characteristics of learning activities (cf. Mulder, 2013), for instance the distinction between individual and social activities, individual and social contexts in which the activities are carried out, and the specific goals associated with each of the three aspects. Responses were recorded on a 6-point Likert type scale ranging from 1 (never) to 6 (all the time). Example items for elaboration included statements such as, “While performing a work task, I deliberately reflected on previous approaches” and “I came up with a new strategy to improve my work and tried it out.” Example items for expansion were, “I observed how other colleagues do something and based on that, developed new ways of working for myself” and “I searched for suggestions to optimise my work.” Example items for externalisation included, “While engaged in a work-related activity, I tried to convince my colleagues of better strategies” and “I provided colleagues with my written ideas for the further development of our work.”

Organisational commitment was assessed using the multidimensional scale by Lee et al. (2001), which captures affective, continuance, and normative commitment. The scale includes 15 items rated on a 7-point Likert type scale from 1 (strongly disagree) to 7 (strongly agree). Example items are "I do not feel emotionally attached to this organisation" (affective commitment, reverse-coded) and "Even if it were to my advantage, I do not feel it would be right to leave my organisation now" (normative commitment).
Emotional exhaustion was measured using the corresponding subscale of the Maslach Burnout Inventory (MBI-D; Maslach et al., 1997). Participants responded to 9 items describing emotional fatigue at work, using a 7-point Likert type scale ranging from 1 (never) to 7 (every day). An example item is: "I feel tired again when I get up in the morning and have to face another day at work."
Job satisfaction was measured using 4 items from the COPSOQ II scale (Pejtersen et al., 2010). Items were rated on a 5-point Likert type scale ranging from 1 (strongly disagree) to 5 (strongly agree). An example item is: "I feel happy when I am working intensely."

Table 15

Overview for work characteristics and their single-item measurements for change

Source	Work characteristic	Definition	Item[1]
Beer & Mulder (2020)	Interruptions (INT)	Extent to which employees have to deal with interruptions frequently	Interruptions to my work through direct communication (e.g., phone calls, chats) have…
	Workload (WL)	Amount of time required to complete work	The time it takes me to complete my work has…
	Physical demands (PHY)	Extent to which the work environment is characterised by physical tasks and movement in general	The amount of physical activity during my working hours has…
	Control by others (CON)	Extent to which employees monitor each other´s behaviour at work	The monitoring of my behaviour by my colleagues has…
	Autonomy (AUT)	Extent to which there is discretion regarding the type, order or time in which work needs to be done	The extent to which I can decide myself when to do which tasks has…
	Responsibility (RES)	Range of tasks and areas of responsibility	The variety of my area of responsibility, including new areas, has…
	Knowledge demands (KNO)	Extent to which specific knowledge and updating the knowledge is required for work	The amount of knowledge required for my work has…
	Opportunities for development (DEV)	Extent to which work provides opportunities and the need for development of skill and knowledge	Development opportunities in my job have…
Mulder & Beer (2020)	Work-life balance (WLB)	Extent to which employees perceive a balance between work and personal life	The separation between my work and my personal life has…
	Quality of communication (QCO)	Quality of communication among colleagues	The quality of communication with colleagues has…
Beer & Mulder (submitted)	External demands (DEM)	Demands of customers and clients regarding the behaviour and content of work	The demands of my clients on my work have…
	Exchange across departments (EXC)	Extent to which cross-departmental and interdisciplinary exchange takes place among employees	The exchange with colleagues from other departments has…
	Attention to detail (DET)	Extent to which attention to detail and concentration are required for work	The number of details I have to consider when completing my tasks has…
	Work comfort (WCO)	Extent to which employees perceive the work as pleasant and not unnecessarily burdensome	How pleasant I find my time at work has…

Note. [1]rated on a 7-point rating scale ranging from -3 = decreased substantially to +3 = increased substantially;

Occupational self-efficacy was assessed with the six-item scale by Rigotti, Schyns and Mohr (2008). Participants indicated the degree to which each statement applied to them on a 6-point Likert type scale ranging from 1 (does not apply at all) to 6 (fully applies). An example item is: “I remain calm when facing professional difficulties because I can always rely on my abilities.”

Technological acceptance was measured with 31 items adapted from the Unified Theory of Acceptance and Use of Technology (UTAUT; Venkatesh et al., 2003). Respondents evaluated each statement with reference to the focal technology they had identified at the start of the survey, using a 7-point Likert type scale ranging from 1 (strongly disagree) to 7 (strongly agree); actual use was recorded with a separate frequency item. Example items include “I find the technology useful for my work” (performance expectancy) and “My interaction with the technology is clear and understandable” (effort expectancy).

Data analyses

To test the hypotheses, both data transformation and multiple statistical approaches were applied, tailored to the nature of the variables involved.

The intensity of change in work characteristics was calculated by transforming participants’ responses on a 7-point scale ranging from –3 ("decreased a lot") to +3 ("increased a lot"). For this analysis, the absolute values of responses were used. This allowed for the isolation of change magnitude irrespective of direction, capturing the degree of change on a 4-point Likert type scale, regardless of whether the perceived change was a decrease or an increase. To examine the direction of change, each participant's response on the 7-point scale was recoded into one of three dummy variables. Responses greater than 0 (i.e., +1 to +3) were coded as an increase, while responses less than 0 (i.e., –1 to –3) were coded as a decrease. Responses equal to 0 were categorised as no change. These variables were used in the subsequent categorical analyses to examine distributional differences in change direction across the different technology groups within the sample.

Hypotheses 1a-c and 2a were analysed using one-way analyses of variance (ANOVAs). In each case, technology type (task-replacing, task-supporting, communication) served as the independent variable. To assess the practical significance of effects, omega squared (ω^2) was reported as a measure of effect size. This choice reflects a more conservative and unbiased estimation, particularly suitable for studies with modest sample sizes, as it adjusts for sampling error more effectively than eta squared. For hypothesis 1a-c, post hoc comparisons using the Games–Howell procedure were conducted to identify specific group differences where the omnibus ANOVAs yielded significant results.

Hypothesis 2b, focusing on the direction of change, was analysed using Chi-square tests of independence based on cross-tabulations between the direction-coded dummy variables and technology type. The likelihood-ratio chi-square statistic (χ^2) was used due to uneven group sizes. As a measure of association, Cramér’s V was reported. This statistic was chosen because it provides a standardised effect size for categorical variables with more than two levels and allows for comparability across tables of different sizes. It is especially well-suited for nominal-by-nominal associations such as those between multiple technology groups and direction categories.

Hypotheses 3a-b were tested using bivariate Pearson correlations and focused on exploring associative patterns between work characteristics and professional development aspects across a broad variable space. Given the exploratory approach and the high number of potential combinations, a simple correlational design split between the technology groups

(task-replacing technologies, task-supporting technologies, communication technologies, no new technologies) allowed for a flexible and data-driven approach without imposing strict directional assumptions. It enabled the identification of emergent relationships, particularly useful in early-stage or applied organisational research, where theory may not yet specify exact pathways. This approach provides empirical grounding for more rigorous generation and testing of future hypotheses as well as theory refinement.
Hypotheses 4-8 were also tested using bivariate Pearson correlations across the whole sample.

6.4 Results

Descriptive results

Means, standard deviations, and internal consistency coefficients (Cronbach's alpha) for all scales are reported in Table 16.

Table 16
Descriptive statistics for all constructs measured with multiple item scales

Construct	Nr. items	α	N	M	SD	Range
Professional development (PD)	24	.79	95	3.34	0.61	1 – 6
Elaboration (ELA)	8	.74	95	3.74	0.91	1 – 6
Expansion (EXP)	8	.79	95	3.11	0.91	1 – 6
Externalisation (EXT)	8	.65	95	3.18	0.78	1 – 6
Occupational self-efficacy (SE)	6	.93	94	4.10	1.18	1 – 6
Technological acceptance (TA)	31	.93	73	4.67	0.86	1 – 7
Organisational commitment (OC)	15	.71	95	3.46	0.71	1 – 7
Affective commitment (AC)	5	.77	95	3.20	0.98	1 – 7
Normative commitment (NC)	5	.65	95	3.55	1.05	1 – 7
Continuance commitment (CC)	5	.85	95	3.64	1.31	1 – 7
Emotional exhaustion (EE)	9	.89	95	2.69	1.02	1 – 7
Job satisfaction (JS)	4	.75	95	3.25	0.76	1 – 5

Hypothesis 1: Professional development depended on types of new technologies

To examine whether professional development differed as a function of technology type (task-replacing, task-supporting, communication technologies, or no new technologies), three one-way ANOVAs were conducted for the professional development subdimensions: elaboration, expansion, and externalisation. Means, standard deviations, test statistics, effect

sizes, and significant post hoc comparisons are displayed in Table 17. Omega squared (ω^2) was reported as a measure of effect size.

Significant group differences were found across all three dimensions. For elaboration, participants using task-supporting technologies reported higher elaboration scores than those using task-replacing technologies. Additionally, elaboration was higher in the group using communication technologies compared to the group using task-replacing technologies.

The strongest difference was observed for expansion. Participants using task-replacing technologies reported more expansion than both groups using task-supporting technologies and communication technologies. Moreover, participants with no new technologies reported higher expansion than those using task-supporting technologies and communication technologies.

Another strong difference was found for externalisation. The participants using task-supporting technologies and communication technologies reported higher externalisation scores than the participants using task-replacing technologies. In addition, the groups using task-supporting technologies and communication technologies each scored higher than the group using no new technologies.

Table 17

Differences in professional development by type of technologies used

	TRT: M (SD) (N=20)	TST: M (SD) (N=31)	CT: M (SD) (N=23)	NT: M (SD) (N=21)	F (df_1, df_2)	p	ω^2	Post-Hoc
ELA	3.14 (0.65)	4.16 (1.00)	3.79 (0.87)	3.64 (0.74)	5.96 (3, 91)	<.001	.14	TRT < TST (p < .001) TRT < CT (p = .041)
EXP	3.78 (0.72)	2.70 (0.89)	2.75 (0.92)	3.48 (0.56)	6.76 (3, 91)	<.001	.23	TRT > TST (p < .001) TRT > CT (p < .001) TST < NT (p = .002) CT < NT (p = .013)
EXT	2.69 (0.68)	3.43 (0.76)	3.52 (0.76)	2.90 (0.61)	3.66 (3, 91)	<.001	.17	TRT < TST (p = .004) TRT < CT (p = .003) TST > NT (p = .038) CT > NT (p = .023)

Note. TRT = Task-replacing technologies, TST = Task-supporting technologies, CT = Communication technologies, NT = No new technologies; ELA = Elaboration, EXP = Expansion, EXT = Externalisation;

Hypothesis 2: Intensity and direction of changes in work characteristics

To examine whether the intensity of change in work characteristics differed depending on the type of technology (task-replacing, task-supporting, communication technologies, or no new technologies), one-way analyses of variance (ANOVAs) were conducted. Table 18 presents the means and standard deviations for each group, as well as F-values, p-values, and effect sizes (ω^2) for each characteristic.

Significant group differences in intensity of change were found for several work characteristics. The most pronounced effects emerged for control, quality of communication, and workload. Other significant differences were observed for work-life balance, opportunities for development, attention to detail, external demands, knowledge demands, autonomy, responsibility, and physical demands. A smaller difference was found for work comfort. No significant differences between technology groups were found for interruptions and cross-departmental exchange.

To test whether the direction of change in work characteristics differed depending on the type of technology used, Chi-square tests of independence were conducted. The likelihood-ratio Chi-square statistic (χ^2) was used to account for unequal group sizes, and Cramér's V was reported as an effect size measure. Table 19 displays the full results.

Significant increases were observed for interruptions, control, work comfort, and quality of communication. For example, communication technologies were more often associated with increases in communication quality, while task-supporting technologies were more commonly linked to increases in control.

Decreases were found in relation to workload, external demands, autonomy, and attention to detail. Decreases in autonomy and external demands were most frequently reported by participants using task-supporting technologies, whereas workload reductions appeared more pronounced in groups not using communication technologies.

Finally, significant differences regarding the "no change" category across several work characteristics were found, including control, workload, and attention to detail.

Hypothesis 3: Changes in work characteristics and professional development

Correlations were calculated for each group representing the three different types of new technologies as well as the sample with no new technologies (see Table 20).

Regarding elaboration, the fewest relationships with changes in work characteristics were found compared to the other aspects of professional development. Changes in the intensity of workload were most strongly related to elaboration within the task-supporting technologies group, while an increase in interruptions showed the strongest relationship with elaboration for the group using task-replacing technologies. For the group using communication technologies, no significant relationships between changes in work characteristics of any kind were identified. Finally, group without new technologies reported an increase in autonomy as well as a dynamic concerning the quality of communication; an increase in the latter was positively related to elaboration.

Table 18

Differences in intensity of change in work characteristics by type of technology used

Work characteristics	TRT: M (SD) (N=20)	TST: M (SD) (N=31)	CT: M (SD) (N=24)	NT: M (SD) (N=21)	F (df_1, df_2)	p	ω^2
INT	1.40 (1.43)	0.94 (0.85)	1.13 (0.80)	1.29 (1.00)	0.99 (3, 92)	.403	.00
WL	1.55 (0.76)	1.03 (0.71)	0.21 (0.41)	1.33 (0.91)	15.46 (3, 92)	<.001	.31
PHY	0.60 (0.68)	0.97 (0.80)	0.58 (0.97)	1.33 (0.79)	4.05 (3, 92)	.009	.09
CON	0.00 (0.00)	0.90 (0.75)	0.70 (0.90)	1.62 (0.80)	17.26 (3, 92)	<.001	.34
AUT	0.45 (0.83)	0.74 (0.77)	0.58 (0.50)	1.33 (0.91)	5.50 (3, 92)	.002	.12
RES	0.50 (0.76)	0.81 (0.75)	0.46 (0.59)	1.24 (0.94)	4.80 (3, 92)	.004	.11
KNO	0.50 (0.69)	0.94 (0.73)	0.38 (0.71)	1.14 (0.73)	5.82 (3, 92)	.001	.13
DEV	0.65 (0.99)	0.84 (0.82)	0.17 (0.38)	1.38 (0.86)	9.13 (3, 92)	<.001	.20
WLB	0.30 (0.66)	0.84 (0.64)	0.58 (0.72)	1.43 (0.81)	9.78 (3, 92)	<.001	.22
QCO	0.10 (0.31)	0.64 (0.75)	1.42 (0.78)	1.20 (0.75)	15.82 (3, 92)	<.001	.32
DEM	0.60 (0.50)	0.84 (0.82)	0.38 (0.65)	1.48 (1.08)	7.83 (3, 92)	<.001	.18
EXC	0.95 (0.76)	1.03 (0.71)	0.92 (0.88)	1.10 (0.94)	0.22 (3, 92)	.883	.00
DET	0.70 (0.73)	1.06 (0.68)	0.17 (0.56)	1.05 (0.92)	8.33 (3, 92)	<.001	.19
WCO	1.35 (0.81)	0.90 (0.83)	1.21 (0.72)	1.57 (0.81)	3.18 (3, 92)	.028	.06

Note. TRT = Task-replacing technologies, TST = Task-supporting technologies, CT = Communication technologies, NT = No new technologies; INT = Interruptions, WL = Workload, PHY = Physical demands, CON = Control, AUT = Autonomy, RES = Responsibility, KNO = Knowledge demands, DEV = Opportunities for development, WLB = Work-life-balance, QCO = Quality of communication, DEM = External demands, EXC = Exchange across departments, DET = Attention to detail, WCO = Work comfort

Table 19

Differences in direction of change in work characteristics by type of technology used

Work characteristic	Direction	% TRT (N=20)	% TST (N=31)	% CT (N=24)	% NT (N=21)	χ^2	p	Cramér's V
INT	Increase	6.7	23.3	56.7	13.3	24.25	<.001	.50
	Decrease	26.5	35.5	2.9	35.5	15.53	.001	.40
	No change	28.1	37.5	18.8	15.6	3.24	.357	.18
WL	Increase	16.1	35.5	16.1	32.3	4.32	.23	.21
	Decrease	39.4	42.4	0.0	18.2	22.80	<.001	.49
	No change	6.3	18.8	59.4	15.6	31.17	<.001	.57
PHY	Increase	16.7	50.0	0.0	33.3	9.20	.027	.31
	Decrease	18.4	31.6	18.4	31.6	3.98	.263	.20
	No change	25.0	25.0	42.5	7.5	16.58	<.001	.42
CON	Increase	0.0	50.0	9.1	40.9	16.33	<.001	.41
	Decrease	0.0	35.7	28.6	35.7	12.04	.007	.35
	No change	43.5	21.7	30.4	4.3	38.23	<.001	.63
AUT	Increase	18.5	25.9	33.3	22.2	1.61	.656	.13
	Decrease	0.0	38.5	19.2	42.3	15.13	.002	.40
	No change	34.9	32.6	23.3	9.3	13.11	.004	.37
RES	Increase	31.8	36.4	0.0	31.8	10.23	.017	.33
	Decrease	0.0	37.9	34.5	27.6	11.18	.011	.34
	No change	28.9	26.7	31.1	13.3	7.56	.056	.28
KNO	Increase	19.4	38.7	6.5	35.5	10.81	.013	.34
	Decrease	9.1	45.5	18.2	27.3	4.33	.228	.21
	No change	27.9	20.9	41.9	9.3	19.47	<.001	.45
DEV	Increase	19.2	26.9	15.4	38.5	6.17	.104	.25
	Decrease	9.5	52.4	0.0	38.1	14.96	.002	.40
	No change	26.5	26.5	40.8	6.1	23.96	<.001	.50
WLB	Increase	19.0	61.9	4.8	14.3	12.45	.006	.36
	Decrease	0.0	26.5	29.4	44.1	23.84	<.001	.50

Table 19

Differences in direction of change in work characteristics by type of technology used

Work characteristic	Direction	% TRT (N=20)	% TST (N=31)	% CT (N=24)	% NT (N=21)	χ^2	p	Cramér's V
	No change	39.0	22.0	31.7	7.3	21.96	<.001	.48
QCO	Increase	5.7	11.4	57.1	25.7	26.60	<.001	.61
	Decrease	0.0	55.0	5.0	40.0	17.13	<.001	.42
	No change	43.9	39.0	7.3	9.8	33.04	<.001	.59
DEM	Increase	43.5	17.4	17.4	21.7	10.23	.017	.33
	Decrease	6.7	46.7	10.0	36.7	15.29	.002	.40
	No change	18.6	30.2	39.5	11.6	10.61	.014	.33
EXC	Increase	29.8	25.5	29.8	14.9	7.74	.052	.28
	Decrease	0.0	63.2	0.0	36.8	20.27	<.001	.46
	No change	20.0	23.3	33.3	23.3	2.35	.50	.16
DET	Increase	35.7	39.3	3.6	21.4	12.07	.007	.36
	Decrease	4.2	58.3	4.2	33.3	18.46	<.001	.44
	No change	20.5	13.6	50.0	15.9	30.39	<.001	.56
WCO	Increase	29.5	11.4	43.2	15.9	26.04	<.001	.52
	Decrease	15.6	46.9	3.1	34.4	16.40	<.001	.41
	No change	10.0	55.0	20.0	15.0	6.26	.100	.25

Note. TRT = Task-replacing technologies, TST = Task-supporting technologies, CT = Communication technologies, NT = No new technologies; INT = Interruptions, WL = Workload, PHY = Physical demands, CON = Control, AUT = Autonomy, RES = Responsibility, KNO = Knowledge demands, DEV = Opportunities for development, WLB = Work-life-balance, QCO = Quality of communication, DEM = External demands, EXC = Exchange across departments, DET = Attention to detail, WCO = Work comfort

Table 20

Correlations between intensity and direction of changes in work characteristics and professional development by type of technologies used

Work characteristic	Change	ELA				EXP				EXT			
		TRT	TST	CT	NT	TRT	TST	CT	NT	TRT	TST	CT	NT
INT	Intensity	-.07	.19	-.07	-.33	-.14	.03	-.32	-.20	.36	.15	-.08	-.17
	Increase	**.45***	.07	-.20	.08	.25	.05	-.27	**.43***	.06	.33†	-.10	**.54***
	Decrease	-.30	.07	.01	-.09	-.28	-.12	.01	-.29	.31	-.21	.01	-.34
WL	Intensity	.03	**.41***	.30	-.21	-.09	**.37***	.27	-.38†	**.47***	**.40***	.14	-.15
	Increase	.01	.15	.30	.02	.29	.06	.27	.01	.05	.11	.14	.27
	Decrease	-.02	.07	.01	-.27	-.25	-.04	.01	-.29	.16	.01	.01	-.34
PHY	Intensity	-.18	.32†	-.13	-.18	-.18	.02	-.30	-.25	.31	.25	**-.43***	-.23
	Increase	-.26	-.02	.01	.12	-.07	.05	.01	-.05	.09	.10	.01	.08
	Decrease	.02	.19	-.14	-10	-.18	-.21	-.33	-.12	.16	.02	-.40†	-.24
CON	Intensity	.01	.17	-.10	-.26	.01	.06	.24	-.17	.01	.14	**-.46***	.28
	Increase	.01	.21	.08	.12	.01	.17	.39†	-.08	.01	.15	.17	-.04
	Decrease	.01	.05	-.29	-.20	.01	-.22	-.07	-.17	.01	-.06	**-.61****	-.01
AUT	Intensity	.22	.29	-.12	.01	.19	-.26	-.36†	-.29	.04	.16	**-.42***	-.17
	Increase	.21	-.21	.03	**.47***	.20	.02	-.25	.38†	-.02	.01	**-.47***	.21
	Decrease	.01	.34†	-.18	-.33	.01	-.16	-.14	-.43†	.01	-.02	.04	-.01
RES	Intensity	.05	.28	-.10	-.26	.31	.12	.09	-.19	.01	.07	.13	-.08
	Increase	-.08	-.04	.01	-.03	.25	.15	.01	.09	.04	.01	.01	**.56****
	Decrease	.01	.16	-.09	-.25	.01	-.22	-.08	-.22	.01	-.14	.26	-.43†
KNO	Intensity	.14	-.23	-.07	.08	.31	.12	.33	-.26	-.01	-.02	-.18	.08
	Increase	.02	-.08	-.01	.33	.32	-.01	-.06	**.47***	-.09	.10	.10	.25
	Decrease	-.14	.11	-.11	-.18	-.02	-.10	.40†	**-.44***	.06	-.10	-.14	-.14
DEV	Intensity	-.05	.23	-.11	.17	.25	-.01	.40†	.08	.01	.12	-.14	-.18
	Increase	.01	.22	-.11	-.23	.29	.22	.40†	.21	.01	.08	-.14	.15
	Decrease	-.14	.08	.01	.26	-.02	-.24	.01	-.22	.06	-.01	.01	-.23
WLB	Intensity	-.29	-.07	.06	.03	.04	-.01	.05	.13	.08	.21	.12	.04

Table 20

Correlations between intensity and direction of changes in work characteristics and professional development by type of technologies used

Work characteristic	Change	ELA				EXP				EXT			
		TRT	TST	CT	NT	TRT	TST	CT	NT	TRT	TST	CT	NT
	Increase	-.29	.23	.01	-.15	.02	.13	.01	-.05	.09	.11	.01	-.20
	Decrease	.01	-.23	-.19	.14	.01	-.26	-.09	.17	.01	-.06	.03	.08
QCO	Intensity	-.14	-.01	.12	-.07	-.02	.02	.15	.01	.06	.17	.02	-.05
	Increase	-.14	.28	-.17	**.47***	-.02	.33†	.07	**.49***	.06	**.42***	-.19	.30
	Decrease	.01	-.14	.01	**-.47***	.01	-.35†	.01	.42†	.01	-.17	.01	-.27
DEM	Intensity	.08	.03	-.07	-.20	.04	.05	**.44***	.06	.16	.24	-.27	-.19
	Increase	.17	-.09	.12	.22	.05	.34†	.18	.20	.12	.21	-.12	.07
	Decrease	-.14	.10	-.11	-.37	-.02	-.21	.40†	-.23	.06	.02	-.14	-.25
EXC	Intensity	.10	.21	.20	-.28	.26	.03	**.55****	-.31	.24	.12	.11	-.07
	Increase	-.07	-.01	.31	-.03	.07	.05	**.44***	.19	.21	.24	.10	.07
	Decrease	.01	.11	.01	-.17	.01	-.20	.01	-.40†	.01	-.18	.01	-.12
DET	Intensity	-.37	.18	.08	-.25	.02	-.03	.39†	-.40†	.15	.09	.17	-.06
	Increase	-.21	-.27	.08	-.21	-.12	.03	.39†	-.22	.22	.13	.17	.17
	Decrease	-.23	.21	.01	-.15	.20	-.19	.01	-.11	-.15	-.19	.01	.02
WCO	Intensity	-.37	.26	-.17	.02	.15	.35†	-.38†	-.25	-.21	.33†	-.01	-.41†
	Increase	.08	-.13	-.22	.01	-.25	**.49****	-.36†	-.23	-.04	.23	-.38†	-.01
	Decrease	-.38†	.20	.08	-.01	.12	-.23	.39†	.03	.01	-.11	.17	-.30

Note. **< .01, *< .05, †< .10; TRT = Task-replacing technologies (N=20), TST = Task-supporting technologies (N=31), CT = Communication technologies (N=23), NT = No new technologies (N=21); ELA = Elaboration, EXP = Expansion, EXT = Externalisation; INT = Interruptions, WL = Workload, PHY = Physical demands, CON = Control, AUT = Autonomy, RES = Responsibility, KNO = Knowledge demands, DEV = Opportunities for development, WLB = Work-life-balance, QCO = Quality of communication, DEM = External demands, EXC = Exchange across departments, DET = Attention to detail, WCO = Work comfort

Regarding expansion, several relationships with changes in work characteristics were identified. Changes in the intensity of workload, as well as an increase in work comfort, were positively related to expansion for the group using task-supporting technologies. No relationships between changes in work characteristics and expansion were found for the group using task-replacing technologies. For the group using communication technologies, positive relationships were observed with changes in the intensity of external demands and exchange across departments, including an increase in the latter. Finally, for the group without new technologies, an increase in interruptions and quality of communication was positively related to expansion. Additionally, a dynamic concerning knowledge demands was identified, with increases positively related to expansion and decreases negatively related.

Regarding externalisation, several relationships with changes in work characteristics were again identified. Similar to other aspects of professional development, changes in the intensity of workload were positively related to externalisation in the group using task-supporting technologies. Additionally, increases in the quality of communication were also positively related to externalisation within this group. For the group using task-replacing technologies, only changes in the intensity of workload were positively related to externalisation. For the group using communication technologies, a dynamic emerged concerning autonomy and control each. Regarding autonomy, an increase was positively related to externalisation, whereas the overall intensity of change was negatively related to externalisation. Concerning control, both a decrease and the intensity of change were negatively related to externalisation. Furthermore, the intensity of changes in physical demands was negatively related to externalisation. Finally, in the group without new technologies, increases in interruptions and responsibility were positively related to externalisation.

Hypothesis 4-8: Correlates of professional development

To test whether professional development was related to individual characteristics and work outcomes, Pearson correlations were calculated. These analyses were conducted across the total sample as well as within technology subgroups (see Table 21 for full results).

In total, few significant relationships were found. Technological acceptance was positively correlated with externalisation. Occupational self-efficacy was closely related to elaboration and expansion, though not reaching statistical significance. Of the work outcomes, only affective commitment was significantly negatively related to elaboration and was close to significantly related to externalisation.

Table 22 provides a final overview of changes in work characteristics, work outcomes, and individual characteristics for which significant relationships with aspects of professional development have been found, organised by type of new technology.

Table 21

Correlations between professional development and work outcomes of professional development (N=95)

		PD total	ELA	EXP	EXT	TA	SE	JS	EE	OC	AC	CC	NC
PD	PD total	1											
	ELA	.80**	1										
	EXP	.60**	.15	1									
	EXT	.71**	.52**	.05	1								
Outcomes	TA	.13	.15	-.12	**.25***	1							
	SE	.17	**.19**†	**.19**†	-.08	.27*	1						
	JS	.06	.06	.09	-.03	.26*	.08	1					
	EE	-.07	-.14	.03	-.05	-.06	-.25*	.04	1				
	OC	-.14	-.12	-.04	-.15	.03	-.04	-.14	-.22*	1			
	AC	-.20*	**-.28****	.05	**-.19**†	-.04	-.10	-.11	-.14	.70**	1		
	CC	.01	.09	-.04	-.03	.07	.03	-.03	-.18	.59**	.03	1	
	NC	-.11	-.08	-.07	-.08	.02	-.03	-.14	-.08	.64**	.43**	-.09	1

Note. **< .01, *< .05, †< .10; PD = Professional Development including: ELA = Elaboration, EXP = Expansion, EXT = Externalisation; TA = Technology acceptance, SE = Occupational self-efficacy, JS = Job satisfaction, EE = Emotional exhaustion, AC = Affective commitment, CC = Continuance commitment, NC = Normative commitment, OC = Organisational commitment total

Table 22

Overview of changes in work characteristics, work outcomes, and individual characteristics for which significant relationships with aspects of professional development have been found, organised by type of new technology

	ELA	EXP	EXT
TST	$_{I}WL_{P}$, ($_{I}PHY_{P}$) , (-AUT_{P})	$_{I}WL_{P}$, +WCO_{P} , (+QCO_{P}) , (-QCO_{N}) , (+DEM_{P}) , ($_{I}WCO_{P}$)	$_{I}WL_{P}$, +QCO_{P} , ($_{I}WCO_{P}$) , (+INT_{P})
TRT	+INT_{P} , (-WCO_{N})		$_{I}WL_{P}$
CT		$_{I}DEM_{P}$, $_{I}EXC_{P}$, +EXC_{P} , (+CON_{P}) , ($_{I}AUT_{N}$) , (-KNO_{P}) , ($_{I}DEV_{P}$) , (+DEV_{P}) , (-DEM_{P}), ($_{I}DET_{P}$) , (+DET_{P}) , ($_{I}WCO_{N}$) , (+WCO_{N}) , (-WCO_{P})	$_{I}PHY_{N}$, $_{I}CON_{N}$, -CON_{N} , $_{I}AUT_{N}$, +AUT_{N} , (+WCO_{N}) , (-PHY_{N})
NT	+AUT_{P} , +QCO_{P} , -QCO_{N}	+INT_{P} , +KNO_{P} , -KNO_{N} , +QCO_{P} , (-QCO_{P}) , (-EXC_{N}) , ($_{I}DET_{N}$) , ($_{I}WL_{P}$) , (+AUT_{P}) , (-AUT_{N})	+INT_{P} , +RES_{P} , (-RES_{N}) , ($_{I}WCO_{N}$)
Individual characteristics	(SE_{P})	(SE_{P})	TA_{P}
Work outcomes	AC_{N}		(AC_{N})

Note. Normal font indicates correlations with $p < .05$, information in parentheses represents correlations with $p < .10$; + = Increase, – = Decrease, $_{I}$ = Intensity; $_{P}$ = Positive relationship, $_{N}$ = Negative relationship; TRT = Task-replacing technologies, TST = Task-supporting technologies, CT = Communication technologies, NT = No new technologies; ELA = Elaboration, EXP = Expansion, EXT = Externalisation; INT = Interruptions, WL = Workload, PHY = Physical demands, CON = Control, AUT = Autonomy, RES = Responsibility, KNO = Knowledge demands, DEV = Opportunities for development, QCO = Quality of communication, DEM = External demands, EXC = Exchange across departments, DET = Attention to detail, WCO = Work comfort; SE = Occupational self-efficacy, TA = Technological acceptance, AC = Affective commitment

6.5 Discussion

Answering the research question

This study investigated how the interplay of new technologies, work characteristics, professional development, work outcomes, and individual characteristics unfolds in the context of finance professionals' work.

The present study demonstrates that different types of new technologies have distinct effects on work characteristics and professional development among finance professionals. Task-replacing technologies are most strongly associated with expansion, task-supporting technologies with elaboration, and communication technologies with externalisation, though with some overlap (sub-question 1). Both the intensity and direction of changes in work characteristics vary significantly by types of new technologies, with communication technologies linked to increases in communication quality, task-supporting technologies associated with enhanced control, and differences found in workload, autonomy, and external demands across types of new technologies. Some work characteristics, such as interruptions or cross-departmental exchange, showed little variation regardless of technology used (sub-question 2). The relationships between changes in work characteristics and professional development are nuanced, as certain changes in work characteristics, such as workload, quality of communication, and interruptions, relate to specific aspects of professional development, depending on the type of new technology and context (sub-question 3). Contrary to expectations, professional development did not show consistent positive relationships with work outcomes such as job satisfaction, emotional exhaustion, or organisational commitment; in some cases, affective commitment was negatively associated (sub-question 4). Finally, individual characteristics such as technological acceptance and occupational self-efficacy played a limited but notable role, with technological acceptance positively related to externalisation and occupational self-efficacy showing a possible, though not significant, association with elaboration and expansion (sub-question 5).

Overall, these findings suggest that the effects of new technologies on professional development and work outcomes are highly differentiated and context-dependent, highlighting the need for tailored support strategies in technology-rich work environments.

Professional Development and its relationships with changes in work characteristics due to new technologies

From the perspective of the various aspects of professional development, and with a focus on them, a detailed discussion can be undertaken regarding their relationships with work characteristics and their dependencies on different types of new technologies.

Elaboration

At its core, elaboration involves learning by drawing on past experiences and applying the lessons learned to new situations (Simons & Ruijters, 2004). As a direct consequence of new technologies, elaboration was highest within the task-supporting technology group. Task-supporting technologies intervene directly within existing workflows, thereby compelling professionals to mentally compare and integrate this new reality with their past experiences.

Regarding changes in work characteristics, increases in workload and interruptions closely relate to one's daily work experience, as they determine task volume and how uninterrupted work can be. Variations in workload intensity can be considered disturbances, disrupting the planned schedule whether the workload rises or falls. Similarly, increased interruptions are generally viewed as challenges to manage, often linked to stress and difficulty completing work, especially in knowledge-intensive domains (Ayyagari et al. 2011). Communication technologies were not associated with changes in work characteristics related to elaboration. It is possible that communication technologies are so well integrated in daily routines that interruptions from them are seen as being expected and do not trigger cognitive disequilibrium. In contrast, interruptions from technologies where interruptions are less expected, such as task-replacing ones, may prompt elaboration due to their surprising nature. In sum, elaboration appears to be employed primarily as a strategy to retrieve past experiences in order to compensate for unplanned or surprising disturbances in work, especially with technologies where this is not expected, such as task-supporting and task-replacing technologies.

Expansion

At its core, expansion involves explicitly learning by researching and seeking new information and knowledge from material information resources or from others (Simons & Ruijters, 2004).

Expansion exhibited the most pronounced differences across the technology groups. Technologies replacing entire tasks or processes tend to create a substantial novelty effect, prompting professionals to seek new information and knowledge to adapt effectively.

Regarding changes in work characteristics, increases in workload intensity for task-supporting technologies, external demands, and exchange across departments for communication technologies may inherently prompt the search for new information. This is reasonable for the exchange across departments, where increased interaction offers opportunities to acquire novel, interdisciplinary knowledge (e.g., boundary crossing; Perz et al., 2010). Changes in external demands also serve as meaningful triggers for finance professionals to engage in expansion when using communication technologies, as prior research suggests (Beer & Mulder, submitted). Given the client-centric nature of the financial sector, it is unsurprising that expansion naturally follows new client demands. Consistent with the original rationale for expansion as a direct response to technological novelty, explicit knowledge requirements or indications of relevant information may especially provoke expansion.

Besides increased exchange across departments, increased work comfort was positively related to expansion for task-supporting technologies. Regarding work comfort, the intensity of change approached a significant positive relationship with expansion, with nearly significant negative relationships in the communication technologies group. These inconsistent dynamics hint at questions of resource use by employees: whether individuals with greater personal resources proactively engage in professional development, may depend on how routine and stable they view their work. There are similarities to for instance the development of innovation, where slowly building upon existing routines is more useful to

foster innovation than big disruptions (Nelson & Winter, 1985). Emerging relationships with work characteristics such as opportunities for development and increased attention to detail also support this rationale.
In the task-replacing technology group, no work characteristic changes were associated with expansion. This aligns with the idea that employees are triggered to engage in expansion directly by the novelty of task-replacing technologies themselves, which shifts awareness away from subtler work characteristic changes following technology use.
In sum, expansion appears to be conducted primarily as a strategy to search for and use new knowledge due to an explicit opportunity or a perceived demand for development triggered by work characteristics that reflect a novel, information-rich, and potentially routine environment, especially shaped by communication technologies and task-supporting technologies.

Externalisation

At its core, externalisation involves learning through sharing knowledge to develop others (Simons & Ruijters, 2004). The communication technology group displayed the highest level of externalisation, closely followed by the task-supporting technology group. The latter warrants further reflection.
Regarding changes in work characteristics, increases in workload intensity were positively related to externalisation in both the task-supporting and task-replacing technology groups. This suggests that workload intensity is a reliable trigger for employees to engage in professional development, specifically externalisation. Changes in work characteristics linked to externalisation in the communication technology group reveal a complex dynamic. Both changes in intensity and decreases in control were negatively related to externalisation. Autonomy showed a similar pattern. In other words, less control and more autonomy appear to reduce externalisation, which contrasts with previous research suggesting that increased autonomy fosters workplace learning (van Ruysseveldt et al., 2011). Communication technologies are known to sometimes have paradoxical effects on communication by simultaneous increases in autonomy and interruptions (Beer & Mulder, 2020). These findings suggest that increased autonomy coupled with decreased control may hinder externalisation by giving employees greater freedom, and reducing the perceived need to share knowledge social ties shift toward greater individual autonomy, lessening immediate information exchange given the ability to communicate anytime and anywhere. Moreover, a less controlled, more autonomous work environment may indicate a less demanding work situation, reducing the need to share critical knowledge (Islam et al., 2024). An emerging negative relationship between increased work comfort and externalisation supports this rationale: externalisation is more likely when individuals feel a strong need to communicate essential information. This contrasts with expansion, for which greater work comfort was linked to higher engagement.
In sum, externalisation appears to be conducted primarily as a strategy to disseminate critical information triggered by work characteristics that reflect an immediate need for social awareness and alertness, especially as shaped by communication technologies and task-supporting technologies.

The relationships between professional development, work outcomes, and individual characteristics

The analysis identified a small number of reliable relationships between professional development and work-related outcomes. Affective commitment was negatively related to elaboration and marginally negatively related to externalisation. Several mechanisms proposed in earlier research may account for this outcome. Employees might develop new skills as preparation for external opportunities (Fugate & Kinicki, 2004), prioritise boundaryless career mobility over organisational loyalty (Hall, 2004), or experience uncertainty and role strain during rapid technological change, diminishing positive feelings towards the employer (Rafferty & Griffin, 2006). Consequently, while professional development appears to support self-efficacy and technology attitudes, it may, under certain conditions, coincide with lower emotional attachment to the organisation.

With regard to individual characteristics that may act as potential moderators of professional development, only a few meaningful associations were identified. Occupational self-efficacy displayed positive, though marginal, correlations with elaboration and expansion, indicating that engagement in these learning activities may enhance employees' confidence, a relationship that could reach statistical significance with larger samples.

Technological acceptance was positively correlated with externalisation. This finding may indicate that favourable attitudes towards technology encourage greater knowledge sharing, or conversely, that articulating tacit knowledge helps employees appreciate the usefulness of new tools; the present data do not permit causal inference.

Limitations and future research

Five key limitations have to be considered. First, the cross-sectional design captures perceptions at a single moment and cannot establish causal order among new technologies, changes in work characteristics, and professional development. Not only directionality, but also potential feedback loops, such as professional development shaping subsequent technology use or perceptions of work characteristics, remain unexplored. Longitudinal approaches are needed to test directionality and observe how learning unfolds over time.

Second, all variables were collected from the same respondents via self-report instruments, raising the possibility of common-method variance and social-desirability bias. Future research should triangulate the findings with for instance behavioural logs or archival data on for instance actual technology use or recorded activities that reflect aspects of professional development (e.g., artifacts to share knowledge produced after engaging in externalisation).

Third, the focus on German finance professionals restricts generalisability, as the transfer of these findings beyond the financial sector may depend on for instance professional norms, organisational structure, or attitudes towards innovation. Remote and hybrid work arrangements, which were not specifically accounted for, may further influence the adoption of new technologies and adaptation to changes in work characteristics. Future research should investigate these contextual variables and for instance stratify samples by work arrangement or compare across different professional domains to better understand the applicability of findings.

Fourth, the sample size was modest, limiting options for data analysis and increasing the risk of Type II errors. Consequently, some potentially meaningful relationships emerged near significance ($p < .10$), warranting cautious interpretation and further exploration (Field, 2024).
Lastly, several constructs were measured with single items (e.g., each technology type and changes in work characteristics). While this reduces respondent burden, it may omit important nuance. The use of validated multi-item scales for these constructs in future research would improve reliability and allow more precise measurement of underlying dimensions (cf. Diamantopoulos et al., 2012).
Taken together, this study provides a foundation for more robust, multi-method investigations into the interplay of technological developments, work design, and professional development.

Practical implications

Finance professionals who are dealing with new technologies and changes at work themselves should develop an awareness for changes in their work and that different technologies might require different and active responses. When working with task-supporting technologies, actively revisiting and adapting established routines can be particularly effective. In environments with task-replacing technologies, actively conducting research, consulting with colleagues, or participating in formal training, can help manage the novelty and complexity these tools introduce. Communication technologies, meanwhile, create new opportunities for exchange where collaborative problem solving becomes especially valuable. Proactively using platforms for knowledge exchange and documenting new approaches supports both individual learning and collective adaptation. At the same time, it is important to remain mindful of one's own well-being and career trajectories, as professional development may sometimes coincide with lower affective commitment to the organisation. Reflecting on how newly acquired skills can be leveraged internally or aligned with long-term goals is, therefore, advisable.

Managers might play a pivotal role in shaping how technological change is experienced and managed. The introduction of new technologies, especially task-replacing tools, might require active support for ongoing learning and timely access to knowledge resources. Ensuring that information about new processes and tools is readily available and signalling that freed-up resources from for instance automation can be redirected towards higher-level tasks are both essential. Where autonomy increases, as is often the case with the spread of communication technologies, setting clear expectations for collaboration and encouraging knowledge sharing are important for preventing reduced information exchange. Anticipating peaks in workload and increases in exchange across departments and industries can enable a very rich workplace with opportunities for development. Protecting time for reflection and learning during periods of change, rather than focusing solely on productivity, helps employees keep pace with technological change and supports both individual and organisational learning. Public recognition of successful knowledge sharing and

externalisation further reinforces a culture of open collaboration and incentivises employees to share their experiences freely.

From a Human Resource Development (HRD) and Human Resource Management (HRM) perspective, interventions should be tailored to the specific types of technologies being implemented. Generic training might be less effective than specific programmes tailored to the specific new technology and its functionalities. Task-supporting technologies benefit from training that encourages employees to refine and optimise current routines. Task-replacing technologies require upskilling opportunities and conceptual knowledge to help staff transition into new or redesigned roles. Communication technologies call for platforms and initiatives that foster real-time knowledge sharing and cross-boundary collaboration. It is recommended that HRD professionals track not just the presence of new technologies, but also how they alter work characteristics such as workload, interruptions, and quality of communication. Establishing feedback loops enables more dynamic support, with interventions adjusted as needs evolve. Designing jobs to include protected time for learning and integrating knowledge sharing into daily practice helps sustain engagement and learning. Finally, fostering technological acceptance through early user involvement, clear communication of benefits, and open discussion of anxieties might further facilitate professional development, particularly knowledge sharing and collaboration. Linking newly developed competences to clear internal career paths can also help retain talent and support long-term organisational success.

Overall, this study underscores the importance of recognising the complexities when managing professional development and work design in technology-driven sectors. By illustrating and testing the nuanced ways in which different new technologies reshape work, professional action and development, these findings lay essential groundwork for future research and organisational practice to more effectively support employees and thus foster resilient, adaptive organisations in an era of rapid technological change.

7 General discussion and reflections

This dissertation examined how new technologies change work characteristics and how those changes relate to professional development, understood as the ongoing development of one´s competences in and through the work of finance professionals. Across three empirical studies, a theoretical framework was developed and applied for generating foundational evidence for this emerging line of inquiry. The evidence shows that new technologies can directly prompt employees in the financial sector to engage in professional development, while at the same time changing a variety of work characteristics, each with diverse relationships with different aspects of professional development.
The following discussion revisits key findings, situates them within the current research landscape, and concludes with practical implications. Explicit connections to the aims of the thesis are made throughout: Chapter 7.1 addresses Aim 1, Chapter 7.2 discusses Aim 2, and Chapter 7.3 focuses on Aim 3 in combination with limitations and an agenda for future research, before practical implications are presented in Chapter 7.4.
Table 23 summarises the results to which the subsequent sections will refer.

7.1 Confirming technologies as drivers of professional development

The first aim of this thesis was to establish whether, and how, new technologies at work prompt professionals to engage in different aspects of professional development. In sum, the results substantiate the theoretical assumption that new technologies directly prompt employees to engage in professional development. Study 2 revealed nuanced relationships and Study 3 added insights, identifying significant differences between aspects of professional development for each type of new technologies. Combining the two concepts enables a more in-depth discussion of each, bringing new facets to light.

7.1.1 Implications for the conceptualisation of professional development

By examining elaboration, expansion, and externalisation in relation to new technologies, important characteristics of these three aspects become apparent.
Elaboration was assumed to be fostered when learning primarily builds on and deepens existing knowledge, which occurs with task-supporting technologies that complement task completion while leaving employees in control. This idea is partly supported by the results of the studies. In Study 2, elaboration also resulted from using task-replacing technologies, specifically a spreadsheet automation that replaced certain calculations but not the entire task, requiring employees to engage deeply with the process. This suggests elaboration arises when new technology affects existing routines, allowing employees to build on prior experience through experiential learning. Thus, the impact of task-replacing technologies on professional development depends on how much of the task completion they replace.

Additionally, elaboration primarily occurred with task-supporting technologies, which aid individual work in one-on-one settings without involving colleagues. Consequently, learning activities here were mainly individual activities in solitary settings such as reflection and deep thinking, positioning elaboration as a mainly internally driven cognitive act (e.g., Boud et al., 1985).

Expansion was assumed to occur primarily when learning depends on gathering new information and knowledge, as is the case with task-replacing technologies that execute sizable portions of the job autonomously and demand new knowledge about both the reconfigured workflow and the technology itself. This idea is broadly supported by the results of the studies. Task-replacing technologies generate strong demands for new knowledge, either due to their novelty or because they extensively replace core tasks, requiring employees to develop a new understanding of their work domain. While minor changes in routines promote elaboration, substantial novelty drives employees to seek new information in order to comprehend the change. By automating parts of the task, these technologies allow employees to focus on novel issues as research on automation posited before (e.g., Brynjolfsson & McAfee, 2014; Autor, 2015). This exploration creates opportunities for conceptual learning through active and explicit knowledge acquisition. Expansion was most strongly linked to task-replacing technologies, which prompted information-seeking about both the technology and the reconfigured workflows. In particular, cross-departmental exchanges triggered by these technologies fostered collective sensemaking, driving collaborative acquisition of new conceptual and procedural knowledge.

Externalisation was assumed to be primarily facilitated by communication technologies, which enable digital interaction among colleagues, managers, and clients, creating opportunities to share experiences and knowledge. This idea has some support from the results of the studies. In Study 2, no direct link was found between externalisation and communication technologies; instead, externalisation occurred mainly with task-replacing technologies, such as when employees explained new systems to management or encouraged interdepartmental collaboration. Conversely, Study 3 showed the highest externalisation among communication technology users, with task-supporting technologies close behind. While Simons and Ruijters (2004) framed externalisation around formal milestones like presentations or publications, Study 2's qualitative data revealed more informal, everyday expressions such as briefings, sharing lessons learned, or persuading collaborators. These subtle forms suggest that externalisation is a low-threshold, routine activity but requires some additional motives beyond the mere availability of the technology, such as organisational norms or individual incentives for collaboration. Contrary to expectations, communication technologies did not automatically increase social learning or knowledge exchange; rather, in the financial sector, communication is rather intentional and organised around compliance and decision-making and less around informal exchange and "chatter" (e.g., Cetina & Bruegger, 2002).

Table 23

Overview of changes in work characteristics, work outcomes, and individual characteristics for which significant relationships with aspects of professional development have been found across all studies, organised by type of new technology

	ELA	EXP	EXT
TST	H , $_{I}WL_{P}$, ($_{I}PHY_{P}$) , (-AUT_{P})	*D* , $_{I}WL_{P}$, +WCO_{P} , (+QCO_{P}) , (-QCO_{N}) , (+DEM_{P}) , ($_{I}WCO_{P}$)	H , $_{I}WL_{P}$, +QCO_{P} , ($_{I}WCO_{P}$) , (+INT_{P})
TRT	*D* , +INT_{P} , (-WCO_{N}) , -*DET*$_{P}$	H , *D* , +*DEM*$_{P}$	*D* , $_{I}WL_{P}$, +*EXC*$_{P}$
CT	H , +*DEM*$_{P}$, -*QCO*$_{P}$	$_{I}DEM_{P}$, $_{I}EXC_{P}$, +EXC_{P} , (+CON_{P}) , ($_{I}AUT_{N}$) , (-KNO_{P}) , ($_{I}DEV_{P}$) , (+DEV_{P}) , (-DEM_{P}) , ($_{I}DET_{P}$) , (+DET_{P}) , ($_{I}WCO_{N}$) , (+WCO_{N}) , (-WCO_{P}) , -*QCO*$_{P}$	H , $_{I}PHY_{N}$, $_{I}CON_{N}$, -CON_{N} , $_{I}AUT_{N}$, +AUT_{N} , (+WCO_{N}) , (-PHY_{N})
Individual characteristics	(SE_{P})	(SE_{P})	TA_{P}
Work outcomes	AC_{N}		(AC_{N})

Note. Normal font indicates quantitative evidence with $p < .05$, information in parentheses represents quantitative evidence with $p < .10$; Italicized font represents qualitative evidence; *D* = Direct effect of the technology (qualitative evidence); H = Highest level of the professional development aspects per technology (quantitative evidence); + = Increase, – = Decrease, $_{I}$ = Intensity; $_{P}$ = Positive relationship, $_{N}$ = Negative relationship; TRT = Task-replacing technologies, TST = Task-supporting technologies, CT = Communication technologies; ELA = Elaboration, EXP = Expansion, EXT = Externalisation; INT = Interruptions, WL = Workload, PHY = Physical demands, CON = Control, AUT = Autonomy, RES = Responsibility, KNO = Knowledge demands, DEV = Opportunities for development, QCO = Quality of communication, DEM = External demands, EXC = Exchange across departments, DET = Attention to detail, WCO = Work comfort; SE = Occupational self-efficacy, TA = Technological acceptance, AC = Affective commitment

Besides the conceptual overlap of the aspects of professional development, empirical evidence suggests these aspects are sufficiently distinct to matter, particularly as their learning activities exhibit different characteristics, such as individual versus social, that may be differentially influenced by specific types of technologies, as argued above.
This finding is especially noteworthy given that Simons and Ruijters (2004, 2014) have repeatedly emphasised the conceptual overlap among these components. For example, within an individual, boundaries blur when a person acquires new information (expansion), experiments with it in practice (elaboration), and simultaneously shares the outcome with colleagues (externalisation). This dynamic also extends between individuals: during a single interaction, one employee may seek information (expansion), reflect on it (elaboration), and share insights gained (externalisation) within the same exchange. While the distinction between elaboration, expansion, and externalisation primarily serves analytic purposes, it proved useful in the operationalisation for the current studies. Compared with alternative conceptualisations of learning at work, the explicit focus on the "learning professional" in Simons and Ruijters' (2004) framework represents a significant conceptual advance over broader notions of workplace learning (e.g., Billett, 2012; Hager, 2011) or informal learning (e.g., Le Clus, 2011; Ellström, 2011). By explicitly linking elaboration, expansion, and externalisation to the ongoing goal of becoming and remaining a professional (Messmann et al., 2010) through refining, testing, and sharing knowledge, Simons and Ruijters (2004) offer a conceptually and empirically robust differentiation and classification of learning activities that other workplace and informal learning models lack.

When considering the broader literature on informal learning, several nuanced issues become apparent. As was discussed in the theoretical background, learning activities can be distinguished along multiple dimensions, including their observability, intention, or whether they are primarily individual or social in nature (Mulder, 2013). Reflecting these characteristics in light of the empirical evidence highlights both the utility and limitations of the framework:
Empirically, elaboration emerged in this research, especially in Study 2, as predominantly an individual activity. Expansion appears to be more ambivalent, encompassing both individual inquiry and social exchange, whereas externalisation is inherently social, typically involving collective engagement or knowledge sharing. This differentiation may present challenges for the conceptual clarity and empirical validity of the framework. If, for instance, the individual versus social nature of learning activities systematically overlaps with the three aspects, this could blur distinctions and complicate adequate measurement. For the present study, the measurements – especially the items for Study 3 – were developed so that all aspects equally reflect all these characteristics. However, whether this reflects the reality of learning at work still needs further analysis. Future research with sufficiently large samples should apply robust factor analytic techniques to gather greater insight into whether the individual-social activity dimension is more influential than previously recognised. This would clarify whether the conceptual and empirical distinctiveness of elaboration, expansion, and externalisation holds up when scrutinised in diverse contexts.

A second consideration concerns the underlying goals of these learning activities. Elaboration and expansion may conceptually appear to prioritise improving one´s own competences and optimising one's own work, while externalisation is oriented towards developing others or the wider organisation. Yet, evidence from Study 2 suggests that this division may be too simplistic. Expansion was frequently undertaken proactively to acquire knowledge relevant to organisational benefit rather than purely individual gain. Conversely, externalisation, while facilitating collective learning, also deepens the competence of the individual articulating and sharing knowledge. Even elaboration, typically conceptualised as self-focused, sometimes entailed experimentation or critical reflection explicitly aimed at improving team or organisational effectiveness later. Thus, at least within the financial sector and among the individuals that participated in the studies within this thesis, the goals of developing oneself and others are closely intertwined and may be equally weighted across all aspects of professional development.

A key future issue may be the precise identification and measurement of the competences that are developed through engaging in these learning activities. The present studies focused on manifest behaviours, such as seeking feedback, experimenting with new tools, or discussing new ideas. However, the contents of the changes in cognitive structures, as described in Piagetian terms, were not directly captured. Understanding how these learning activities translate into specific competence gains could be crucial for advancing both theory and practice of learning at work. Such an investigation could build on the findings of this thesis, which revealed that engaging in professional development can encompass competences ranging from the skilful use of a new technology to the potential redefinition of one's professional identity and roles. Given the broad spectrum of competences that may be developed, future research should prioritise clarifying these competence gains and explicitly connecting them to learning activities. With the current state of findings, we know *that* learning occurs, but we still do not fully understand how.

In conclusion, despite international research on professional development increasingly recognising its ongoing nature compared to formal professional development initiatives (Webster-Wright, 2009; Bierema, 2016), comprehensive conceptualisations are still lacking (cf. Coady, 2024; Lundgren & Poell, 2024). This thesis has demonstrated that the framework from Simons and Ruijters (2004) can be empirically grounded and meaningfully related to elements of work such as types of new technologies and changes in work. Therefore, it constitutes a valuable framework for clustering learning activities linked to other workplace phenomena.

7.1.2 Implications for the conceptualisation of new technologies in the financial sector

The empirical relationships we observed between aspects of professional development and types of new technologies suggest that the specific characteristics of those technologies

matter, perhaps more so in the highly regulated and individual-focused context of the finance domain. Task-supporting technologies in this setting tend to be introduced for compliance and regulatory purposes, supporting mainly individual work processes without fundamentally changing task ownership. In contrast, task-replacing technologies, while also targeting individual tasks, proved especially effective at promoting information exchange across departments, rendering them social technologies in their own way. Communication technologies, although valued by finance professionals, were deployed in deliberate, thoughtful exchanges; indeed, users reflected even on the frequency of digital interactions, and there was no automatic, thoughtless increase in communication. This effect again may be an interaction between the technology and the professional domain as there may be different organisational cultures regarding communication in other professional domains.

The results further indicate sufficient variation to demonstrate meaningful differences in professional development, thereby confirming the utility of the typology proposed by Mulder et al. (2022). Nevertheless, there remains scope to refine these types further. Returning to Autor et al.'s (2003) task-based approach, it could be useful to distinguish more precisely whether a task-replacing technology automates only part of a task, generating an intermediate output that requires employee engagement, or replaces the entire task, delivering a finished output that may bypass direct interaction. The former scenario is liable to invoke elaboration, as Study 2 showed when employees needed to understand a spreadsheet automation's inner workings to make effective use of its results. By contrast, wholly replaced tasks may curtail opportunities for learning activities, for instance prompting externalisation, as again Study 2 showed. A more granular analysis of how new technologies intersect with individual work tasks could trace each task's outputs as they circulate through the organisation and are taken up by colleagues, who, in turn, engage in different learning activities. Such "handoff" tracking might reveal the complex interplay between technological change and the professional development dynamics outlined above, especially given Study 1's finding that some technologies simultaneously changed the work performed by multiple groups.

In addition, and building on this, an adjustment of the broad category of communication technologies may be worthwhile as it is conceptually the weakest of the three types. Unlike task-supporting or task-replacing technologies, which centre on concrete work tasks, communication technologies target a function across tasks (i.e., communication). Consequently, their theoretical link to professional development (via externalisation) was the least coherent and yielded the most heterogeneous outcomes. A promising conceptual refinement would be to integrate communication technologies into the task-based framework rather than treating it as a standalone category. This adjustment would simplify the typology (reducing it to task-supporting and task-replacing) while opening up new subtypes for detailed analysis. Building on the insights generated by this thesis, future research could compile domain-specific technology inventories and cluster them according to how they ideally interact with task completion.

7.2 Focusing on changes in work characteristics relating to professional development

The second aim of this thesis was to investigate how new technologies change work characteristics and how these changes, in turn, prompt employees to engage in professional development. To address this, Study 1 provided a systematic review of how various technologies impact work characteristics across professions, while Study 2 identified additional, profession-specific changes in the financial sector and linked them to aspects of professional development. Building on these insights, Study 3 quantitatively tested these relationships and further explored the associations between professional development, individual characteristics, and work outcomes. Overall, the investigation of changes in work characteristics presents a highly complex picture, which both advances the conceptual development of this research and quickly reveals the limitations of existing approaches.

7.2.1 Themes as descriptors of complex changes at work

Several work characteristics, initially identified inductively in Study 1, expanded with new characteristics from Study 2, and ultimately operationalised for quantitative research in Study 3, individually align with characteristics from established models (e.g., Hackman & Oldham, 1975; Karasek, 1979; Morgeson & Humphrey, 2006). For these work characteristics for which relationships with professional development were found, a complex picture emerges (see Table 23). For some work characteristics, only intensity mattered, in others only increases or decreases did; and sometimes a combination of different types of change played a role. Overall, based on the theoretical arguments around Piaget's equilibration, it is reasonable to conclude that changes in these characteristics indeed hold the potential to prompt employees to engage in professional development, across various work characteristics and types of change. However, by far not all work characteristics were associated with professional development, and among those that were linked to its different aspects, discernible patterns emerge.

Research on work design has a history of identifying and clustering discrete work characteristics theoretically by linking them to a specific outcome, for instance experienced meaningfulness and motivation in the Job Characteristics Model (Hackman & Oldham, 1975) or job satisfaction in the SMART framework (Parker & Knight, 2024). In a similar manner, the individual changes in work characteristics observed in the course of this thesis that were related to professional development, will be organised into higher-order themes in order to reduce complexity and to gain a clearer sense of the work environment that may emerge from their unique characteristics.
The term "themes" is chosen as it implies a flexible, context-dependent label, whereas the observed changes in work characteristics are closely tied to specific technologies and vary by domain. Themes offer an interpretative description of the full range of changes that

emerged across the cells of Table 23 from diverse analyses and empirical data. Although some changes in work characteristics appear in multiple cells, the unique combination of changes in each cell, mediated by differences in the types of new technologies, ensures that the resulting themes are unique and distinct. Moreover, themes acknowledge the temporal and contextual nuances of workplace dynamics (compared to for instance fixed "categories; Braun & Clarke, 2006), allowing an understanding of how particular configurations of work characteristics and technologies create emergent patterns. Given the move to conduct research where organisational phenomena are better understood as processes of becoming rather than static entities (e.g., Tsoukas & Chia, 2002; Van de Ven & Poole, 2005), the thematic approach is suitable for this approach and renders the research open to further investigations.

Figure 8 consolidates these themes and introduces the terminology used in the following discussion: (a) *Routine fluctuations*, describing varying degrees of operational disruption, minor workload shifts or spikes in interruptions, that characterise an environment that requires employees to adapt and refine routines through elaboration ; (b) *Demand-driven enrichment*, describing an abundance of opportunities to learn alongside explicit demands for deeper understanding that jointly creates an environment that requires and enables employees to extend their knowledge through expansion; and (c) *Contingent connectivity*, describing social conditions that reflect varying levels of urgency and necessity to share knowledge and creates an environment in which knowledge-sharing becomes contingent on necessity rather than unfolding automatically.

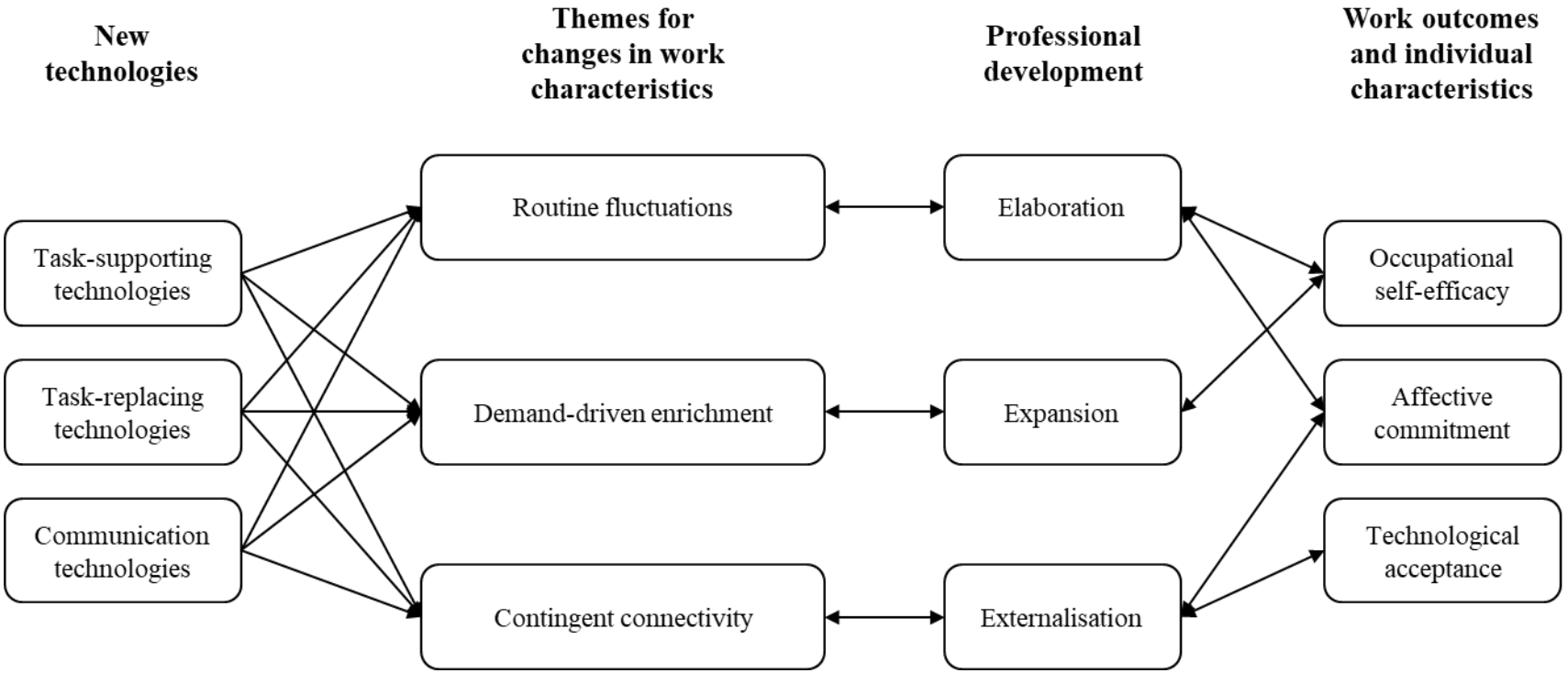

Figure 8. *Depiction of variables exhibiting significant relationships, centered around the themes for changes in work characteristics*

Routine fluctuations summarise the changes in work characteristics that, across all types of new technologies, have led to elaboration. It broadly depicts a work environment in which varying fluctuations in the daily schedule (e.g., intensity of workload) and in employees' normal routines (e.g., increase in interruptions) create deviations that require staff to fine-tune and adjust their work processes. This theme highlights how varying degrees of disruption, whether minor workload shifts or heightened interruptions, act as triggers to adapt established routines. In Piagetian terms, such deviations elicit assimilation processes, prompting employees to adapt and refine rather than overhaul their cognitive models. Minor but frequent deviations in workload or interruptions create Piagetian disequilibrium and prompt employees to engage in elaboration as they fine-tune existing know-how.
This theme resonates strongly with several theories, foremost among them the perspective on innovation development proposed by Nelson and Winter (1985). They argue that gradual change and adaptation of organisational routines over time lead to innovation, reflecting an evolutionary view of how organisations develop. The theme of Routine Fluctuations captures precisely these smaller, non-catastrophic variations in routines that nevertheless require a response. At the individual level, this theme aligns well with concepts such as job crafting (Tims & Bakker, 2010), which involves adapting one's approaches to tasks and reflecting on them in ways that are not necessarily radically disruptive but rather incremental (Petrou et al., 2018) and was recently conceptualised as a bottom-up mechanism that serves as a counterbalance to formal top-down work design (Parker et al., 2025).
Thus, this theme connects meaningfully with theories of innovation development, work design, and work behaviour, stressing the utility of small variations in the day-to-day experience of work.

Demand-driven enrichment summarises the changes in work characteristics that, across all types of new technologies, have led to expansion. It broadly depicts a work environment that combines an abundance of new information and the broadening of relevant knowledge (e.g., increase in exchange across departments) with a simultaneous recognition that additional knowledge or skills are needed (e.g., increase in external demands). This theme brings together the idea that substantial novelty and information resources compel employees to go beyond their existing cognitive models, actively seeking out, testing, and integrating new conceptual and procedural knowledge. In Piagetian terms, these high-intensity intrusions demand accommodation to restore cognitive balance. The work context is not only rich in novelty but also explicitly demands deeper understanding and skill acquisition, signalling that new knowledge must be constructed to maintain equilibrium.
This theme again connects with organisational theories, specifically the idea of ambidexterity and the associated exploitation vs. exploration dynamic in organisational learning (e.g., March, 1991; Luger et al., 2018). This perspective emphasises, at the organisational level, the dynamic balance between fully leveraging existing knowledge (i.e., exploitation) and integrating new knowledge (i.e., exploration). Reflected in the theme identified here, it suggests a culture and work environment where employees independently recognise and address knowledge gaps, balancing the effective use of their professional expertise against emerging external demands. At the individual level, this theme aligns with

the concept of specifically challenge-hindrance demands from the Job Demands-Resources (JD-R) model (Demerouti et al., 2001), which similarly highlights that certain demands, when accompanied by adequate resources, can have positive effects (e.g., Kim & Beehr, 2018).
Thus, this theme connects meaningfully with theories on organisational learning and work design stressing the synergy of the simultaneous presence of opportunities and demands for development.

Contingent connectivity summarises the changes in work characteristics that, across all types of new technologies, were related to externalisation. It broadly depicts a work environment in which a perceived urgency to share information decreases, either because social control is decreasing or because shifts in roles and responsibilities make it less necessary to pass on new information to others (e.g., increase in autonomy). Rather than presuming that externalisation simply increases with every new communication channel or demand, this theme recognises that knowledge-sharing is selectively triggered, or inhibited, by shifts in autonomy, control, or communication intensity. In Piagetian terms, externalisation may take part of the accommodation process when individual assimilation is insufficient to resolve disequilibrium, thereby prompting collective sense-making. Under some conditions (e.g. increase in quality of communication) the need to articulate insights spikes; under others (e.g. increase in individual discretion) the impetus to externalise recedes.
This theme connects with theories on social capital such as brokerage theory (Burt, 2005), emphasising that that information flow is contingent on the location and the relationships between actors. That includes certain structural and cultural conditions – reflected in the levels of individual discretion or social control – as critical success factors for effective knowledge brokering (e.g., Hargadon, 2002). In addition, this finding resonates strongly with DeSanctis and Poole's (1994) Adaptive Structuration Theory (AST), which emphasizes that the communication structures created by technologies do not necessarily translate directly into the communication patterns that emerge from the social dynamics surrounding those technologies. Thus, this theme connects meaningfully with theories on social capital and information systems, stressing the importance of social contingencies as critical factors shaping actual social exchange and therefore learning.

Categorising work characteristics into overarching themes is of course illustrative, yet it displays interesting connections to different theories that may be valuable for this research. The unique added value of this approach lies in the fact that these overarching themes are not merely labels for work characteristics but actively attempt to represent how these characteristics are evolving and interacting with each other instead of just being static in a sense.
Since Study 1, the analysis of work characteristics revealed several interconnections and complexities that allow for a more nuanced description of work dynamics, often involving paradoxes that cannot be captured by focusing solely on individual work characteristics. For instance, information and communication technologies were found to create a paradoxical situation: while they increase autonomy for individual employees, which is generally viewed

positively, they also lead to more interruptions, an effect that is largely perceived as negative. This exemplary comprehensive description of the context now enables more fine-grained research, allowing for a detailed exploration of employees' experiences as they navigate these tensions. Rather than simply contrasting individual work characteristics, this approach makes it possible to capture how employees actively shape and are shaped by their dynamic work environments. Such a nuanced understanding is necessary to develop more ecologically valid research, which in turn will enhance our ability to study and support professional development in situations of ongoing organisational change. Another key theme identified was the presence of spillover effects, where the introduction of new technologies affected not only the targeted occupational groups but also had ramifications for other professions. These spillover effects led to different patterns of change in work characteristics for different professional groups, highlighting the complex and interconnected nature of technological change within organisations.

In sum, by being able to organise the various changes in work characteristics into the three overarching themes of change, this study demonstrates that meaningful themes in relationship to professional development emerge especially when attention is paid not just to the characteristics themselves but also to the direction and intensity of their change and the environment that all changes combined convey.

7.2.2 Initial evidence for work outcomes and facilitating individual characteristics

Testing the relationships between aspects of professional development and various work outcomes revealed comparatively few significant relationships. Some relationships were only close to significance and thus require careful interpretation.

Two negative correlations stand out as particularly interesting regarding the relationships between professional development and work outcomes, one of which is statistically significant, and the other nearly so. These involve the affective commitment dimension of organisational commitment and two of the three aspects of professional development: a significant relationship with elaboration and a near-significant relationship with externalisation. The negative correlations with this particular dimension of organisational commitment do not align with the theoretical assumptions. It was initially expected that professional development, given its potential effects and its role in benefiting the organisation, would rather foster emotional attachment to it. However, employees´ professional development may weaken their affective commitment for three related reasons. First, many employees intensify professional development when they expect to leave; acquiring new skills prepares them for potential other projects, so their emotional attachment to the current employer fades (Fugate et al., 2004). Second, some employees value mobility and external networks more than loyalty to any single organisation; sustained professional development therefore strengthens identification with the wider occupation while decreasing feelings for the firm (Hall, 2004). Third, the setting was one of change due to new technologies and the data was cross-sectional: although professional development may help

employees cope with time, the same turbulence brings uncertainty, heavier cognitive load and role ambiguity, all of which erode positive feelings toward the organisation at the time of the survey (Rafferty & Griffin, 2006). Together these mechanisms explain why increased professional development can coincide with reduced affective commitment even when the organisation still benefits from the enhanced skills.

Regarding individual characteristics potentially being moderators of professional development, occupational self-efficacy was positively related to aspects of professional development, specifically elaboration and expansion, but correlations were just approaching significance.
Given the small sample sizes of the individual groups, it cannot be ruled out that these correlations might become significant with larger datasets and increased sample sizes. While these results should not be overinterpreted at this stage, it is noteworthy that occupational self-efficacy emerges in relation to two of the three aspects of professional development. It is reasonable to assume that employees with higher self-efficacy are more inclined to engage in professional development activities, particularly during periods of change and when confronted with new technologies (Lunenburg, 2011) and that, conversely, engaging in professional development may further reinforce these self-efficacy beliefs, creating a reciprocal relationship (Salanova et al., 2011).
Furthermore, the significant positive correlation observed between technological acceptance and externalisation suggests that technological acceptance may also act as a predictor of professional development. Technological acceptance, as operationalised here, encompasses personal assessments of a technology's usefulness and usability, individual motivation and anxieties, as well as perceptions of colleagues' and supervisors' attitudes towards the technology. Employees with greater acceptance of new technologies are more likely to engage in externalisation, explicitly sharing knowledge and reflections that shape attitudes toward technology. Conversely, given the correlational nature of the data, the direction of causality cannot be conclusively determined; it is also possible that increased externalisation (especially on the topic of new technologies) fosters more positive technological acceptance. For instance, as suggested by Study 2, individuals highly convinced of the benefits of task-replacing technologies actively promoted their use and identified cross-departmental applications, indicating that high technological acceptance and externalisation can reinforce each other. In conclusion, the identification of the role of individual characteristics remains very limited, reveals unexpected results, and requires systematic investigation in the future.

7.3 Limitations and implications for future research

The third aim of this thesis is to critically appraise existing conceptualisations, theoretical frameworks, and methodological approaches regarding new technologies, changes in work characteristics, and professional development. This appraisal draws on the exploratory decisions made throughout the studies to inform future research that more fully integrates these phenomena in contemporary workplaces. This is best done by discussing the

limitations and implications for future research as a critical appraisal of the choices for this research has implications for both equally.

7.3.1 Appraisal of concepts

The thesis examined a range of key constructs, many of which have been discussed in detail elsewhere; however, the following section provides a concise appraisal of these concepts and their application within this research context.

New technologies

The typology developed in Mulder et al. (2022), distinguishing task-supporting, task-replacing, and communication technologies proved effective in explaining differences in how employees engage in professional development. The categorisation revealed meaningful patterns, notably that task-supporting technologies primarily fostered elaboration, task-replacing technologies triggered expansion, and communication technologies supported externalisation. However, conceptual challenges remain. For example, communication technologies, by definition, cut across many work tasks, blurring the boundaries between categories. As such, a more task-based conceptualisation, rather than categorising by broad technology function, might offer greater precision in future research (Autor et al., 2003). Furthermore, the rapid pace of technological change suggests the need for continuous refinement of typologies, as technologies evolve or converge in their functionality.

Another limitation is that most conceptual models treat technology as exogenous, i.e., something imposed on work, whereas in other areas of research, the integration and adaptation of technology are often co-determined by professional cultures and organisational context (Orlikowski & Scott, 2008). Future conceptual work should account for this socio-technical dynamic, but this also requires adapting research methods as necessary and carefully considering whether such an approach is compatible with the chosen research paradigm.

Professional development

Focusing on Simons and Ruijters´s (2004) elaboration, expansion, and externalisation offered a useful framework for distinguishing types of learning activities in professional contexts. Empirically, these categories were largely distinguishable, supporting the utility of the framework. Yet, the studies highlighted several nuances. For example, elaboration was mostly individual, expansion alternated between individual and social, and externalisation was predominantly social. This raises the question of whether the social vs. individual dimension might, in some cases, be as salient as the framework itself (cf. Mulder, 2013).

Additionally, the goals underlying each aspect may overlap more than previously assumed: even activities aimed at improving one´s own situation (i.e., elaboration or expansion) often contributed to team or organisational outcomes, while externalisation also deepened the individual's expertise. Thus, the distinction between goals to develop oneself or others may

not be as clear as expected. Future research should explore how goals and social context intersect with these aspects.
A persistent black box is the precise identification of competences developed through professional development activities. The present studies observed manifest behaviour but did not attempt to identify the contents of cognitive structures after learning took place. Connecting observable activities to underlying competence development remains a crucial task for advancing both theory and practice (cf. Coady, 2024).

Changes in work characteristics
The approach taken in this thesis – viewing work characteristics not as static variables but as evolving themes – represents, at minimum, a valuable conceptual development and, at best, a significant advance in understanding workplace dynamics. Focusing on the direction and intensity of changes (i.e., Mulder et al., in progress) is a useful approach to measuring change because as was shown, direction and intensity sometimes vary in their relationships with other aspects of work. Adding to this, the themes developed in this thesis try to capture the dynamic and interrelated nature of different changes in various work characteristics.
By distinguishing themes for change, the thesis provides a concise lens linking patterns of change to elaboration, expansion and externalisation. The framework complements established work-design models by emphasising direction and intensity of change instead of static categories and demonstrates that professional development is both a route to adaptation and has some associations with other work outcomes.
However, these themes remain provisional, shaped by both technology type and professional context. It remains to be seen whether the same themes would emerge in different sectors or with other technologies. The mapping of themes was also largely inductive; future research could test and refine these themes deductively in more diverse samples, and of course, test them empirically.

7.3.2 Appraisal of methods

Methodologically, the three-study design, i.e., combining a systematic review, qualitative interviews, and a quantitative survey, allowed for a multifaceted investigation. However, several methodological limitations should be noted.

Systematic review (Study 1)
The review was exploratory and did not initially categorise evidence by technology type, which limited the ability to directly compare with later studies. Future reviews should use a refined typology from the outset for more targeted synthesis and comparison.

Qualitative interviews (Study 2)
While the interview study yielded rich and nuanced data, the sample size is modest and specific to the financial sector, which may introduce selection bias and limit generalisability. The inductive identification of work characteristics means that some profession-specific

traits may have been overemphasised, while others were overlooked. Qualitative research in additional sectors or combining interview data with for instance ethnographic observation or longitudinal designs would strengthen the external validity and ecological depth of findings.

Quantitative survey (Study 3)
The cross-sectional survey with modest subgroup sizes restricted the complexity of statistical analysis and increased risk of both Type I and Type II errors. Reliance on self-report measures raises concerns about common method variance and social desirability bias. The use of single-item indicators for key constructs (technology type, work characteristic changes) reduced respondent burden but may have limited validity (Diamantopoulos et al., 2012). Future work should use multi-item validated scales and supplement self-report with behavioural or archival data.
Most crucially, the cross-sectional design precluded inferences about causality or temporal dynamics. Longitudinal, experience sampling, or intervention-based research will be necessary to disentangle the sequencing and feedback loops among new technologies, work characteristic changes, and professional development.

7.3.3 Appraisal of the profession

The empirical work in this thesis was conducted almost exclusively within the German financial sector. This context brings both strengths and limitations for the transferability of findings.

Professions selecting for individual characteristics
The financial sector, as observed in this thesis, may attract individuals who are highly organisationally oriented, proactive, and performance driven. This self-selection could partly reflect the strong client orientation and emphasis on measurable outcomes typical of banking and finance. As the interviews suggest, professionals in this field often display pronounced self-efficacy and solution-oriented attitudes, possibly shaped by industry norms that emphasise professionalism and competence, while also discouraging open discussion of problems in favour of maintaining performance. Such characteristics could significantly affect how change is experienced and managed. Employees may adapt more readily to new technologies and workplace change or at least be socialised to present such adaptability.

When considering the transferability of these findings, it is critical to recognise that characteristics like client orientation are not universal across professions. For instance, external demands were frequently associated with professional development, a relationship likely shaped by the sector's norms. In contrast, professions less inclined to these norms, such as the arts or early childhood education, may neither face the same external demands nor value technological adoption as highly. Conversely, domains such as healthcare, legal

services, and auditing share similar compliance requirements and information intensity, making them more comparable reference points for transfer.

Non-optionality of certain technologies

Another domain-specific aspect is the non-optional nature of many new technologies in finance, especially since the global financial crisis. Regulatory requirements often necessitate the adoption of task-supporting technologies, leaving little room for personal or organisational resistance. As a result, constructs like technological acceptance may play a different role in this context. Adoption is not always a matter of choice, but of necessity. This was particularly visible during the COVID-19 pandemic, when the adoption of communication technologies became essential for continued client interactions. Here, technology was not just integrated smoothly. It was required for business continuity, reducing variability in acceptance.

By contrast, task-replacing technologies such as artificial intelligence or blockchain are often perceived as high-potential, performance-enhancing tools in the finance sector, and therefore tend to be enthusiastically adopted, potentially with less resistance than in more traditional fields. These findings underline the importance of profession-specific dynamics when interpreting relationships between new technologies, work characteristics, and professional development.

Organisational structures

Despite the apparent fit between the financial sector and new technologies, large organisational structures pose their own challenges. The research, especially the interview study, revealed that even in highly tech-affine environments, implementation is often hampered by bureaucratic processes, hierarchical decision-making, and legal or compliance restrictions (e.g., data protection, works councils, regulatory agencies). These organisational constraints can delay or complicate technology adoption, regardless of employee acceptance. This may contrast sharply with, for instance, start-up environments, where flatter hierarchies and fewer regulatory constraints typically enable much faster adoption and iterative development of new technologies. Future research should therefore consider these organisational factors when generalising findings to other sectors, particularly to those with fewer regulatory obligations or different organisational cultures.

7.4 Practical implications

Across the three studies included in this thesis, a range of practical implications can be derived for different groups.

For finance professionals

Professionals working in technology-driven environments should actively develop an awareness for how different new technologies affect their work and recognise that each technology type may demand distinct responses and skills. When dealing with task-

supporting technologies, intentionally revisiting, questioning, and adapting established routines can be highly effective. In the context of task-replacing technologies, seeking new information, consulting with peers, and engaging in formal or informal training become essential for navigating increased complexity and novelty. Communication technologies, on the other hand, provide new avenues for knowledge exchange and collaborative problem solving; proactively participating in these exchanges and systematically documenting best practices supports both individual learning and collective adaptation. The findings highlight the value of job crafting: employees who shape their roles and proactively manage their own professional development in response to technological change demonstrate greater adaptability (Wrzesniewski & Dutton, 2001). Additionally, professionals should be mindful that changes in work characteristics can have hidden or less visible effects on roles and wellbeing. Reflection on personal career trajectories, internal opportunities for applying new skills, and regular self-assessment of stress and commitment levels are advisable to ensure personal development does not come at the cost of wellbeing.

For leadership and managers

Leaders play a pivotal role in creating an environment where professional development is both possible and encouraged during technological change. The results suggest that management must actively support employees' learning, provide timely access to knowledge resources, and explicitly communicate opportunities for interdisciplinary and interdepartmental exchange (Wenger, 1998). Recognising the subtle and sometimes invisible shifts in roles and tasks triggered by new technologies is critical: leaders should encourage regular check-ins and create platforms where changes and challenges can be surfaced and discussed openly. Increases in autonomy, often a consequence of communication technology adoption, must be balanced with clear expectations for collaboration and public recognition of knowledge sharing. Anticipating workload peaks, supporting time for reflection, and signalling that resources freed by for instance task-replacing technologies should be reinvested in value-adding tasks or exploration of new opportunities can help buffer the challenges associated with change. Importantly, managers should cultivate a readiness for change across the organisation, so that opportunity spaces created by new technologies can be leveraged by all, not just the most proactive.

For Human Resource Development (HRD) and Human Resource Management (HRM) professionals

HRD and HRM practitioners must move beyond generic interventions and tailor professional development initiatives to the specific technologies and changing work characteristics in their organisations. For task-supporting technologies, training should emphasise the refinement and optimisation of existing routines; for task-replacing technologies, upskilling and reskilling initiatives are required to facilitate smooth role transitions. Communication technologies demand platforms for real-time knowledge sharing and collaborative learning. The results suggest a need for cultivating self-directed learning, time management, and social skills that support trust and openness, especially in technology-rich environments (Thomas et al., 2009; Germain, 2011). HRD should encourage the formation of Communities

of Practice (Wenger, 1998), encourage experience-based and flexible learning formats (Spiro et al., 2003), and provide assessment strategies that promote skill and knowledge acquisition, as well as attitudinal change (Dolmans et al., 2005; Gulikers et al., 2004). Furthermore, early involvement of actual users while introducing new technologies, transparent communication about benefits and challenges, and regular feedback mechanisms are recommended to promote technological acceptance and openness to change (Venkatesh et al., 2003; Straub, 2009). HR should also ensure that assessment and evaluation as well as incentive management are aligned with learning objectives to sustain development and support career progression within the organisation.

Overall, the findings of this thesis underscore that supporting professional development in technology-driven workplaces requires coordinated action at the individual, managerial, and organisational levels. By recognising the distinct demands of different technologies, fostering open communication, and providing dynamic, tailored learning environments, organisations can better equip their workforce to thrive amid ongoing technological and organisational change. This approach not only supports employee wellbeing and performance but also builds resilience and adaptability for the organisation.

8 Concluding remarks

Referring back to the central research question – how different types of new technologies impact work characteristics and professional development, and how changes in work characteristics relate to professional development and its associated work outcomes – this thesis provides the following answers:

Employees engage in professional development through the distinct but interrelated aspects elaboration, expansion, and externalisation, which likely correspond to types of new technologies. Task-supporting technologies primarily elicit elaboration, involving the refinement and adaptation of existing knowledge and routines. Task-replacing technologies primarily elicit expansion, characterised by active acquisition of new conceptual knowledge and skills. Communication technologies primarily elicit externalisation, facilitating the articulation and sharing of tacit knowledge within the social context.
Professional development is in turn related to the intensity and direction of changes in work characteristics, such as workload or quality of communication, and is further moderated by individual characteristics including occupational self-efficacy and technological acceptance. Regarding work outcomes, professional development showed limited relationships with job satisfaction and emotional exhaustion, but was unexpectedly negatively related to affective organisational commitment, suggesting complex underlying mechanisms potentially linked to career mobility or organisational change dynamics.
In sum, professional development constitutes a dynamic, contextually embedded phenomenon shaped by the interplay between types of technologies, changes in work characteristics, individual characteristics, and related work outcomes.

As technologies continue to evolve, researchers and practitioners will benefit from monitoring not only which tools are deployed, but also how they change day-to-day experiences at work that ultimately lead to professional development. A focus on changes in work characteristics therefore offers a practical pathway for sustaining professional development in workplaces that are subject to ever-changing societal shifts and the challenges they entail.

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—Nietzsche (1878), Aphorismus 499

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