Volume 17 • Issue 3 • 2025

Engineering Management in Production and Services

received: 10 May 2025
accepted: 30 July 2025

pages: 51-67

Key elements of digital competence in professional sales & service work: Development and evaluation of a self-assessment scale for frontline employees

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A B S T R A C T
Modern work in sales & service is increasingly enhanced and supported by digital technologies. As a result, frontline employees' digital competencies are becoming a key success factor for sales & service work. Nevertheless, especially with regards to professional work, there is still a lack of knowledge about how to measure digital competencies. So far, specific empirical contribution focussing on professional digital work environments being increasingly knowledge-intense, collaborative, and virtualized are still very rare. In this article we seek to make a substantial contribution in that area of research. Based on the state-of-the art literature about digital competence among employees in professional work this article is one of the very few that introduces an empirically evaluated scale of digital competence based on a sample size of N=1,283. We suggest a context-related set of five dimensions of digital competence named (1) effective usage of technologies and tools, (2) farsighted & critical information handling, (3) sustained cooperation & communication, (4) integrative knowledge generation, and (5) co-creative problem solving. Evaluation of these five dimensions is conducted with the help of technostress, virtualization of work, space-time flexibility at work and availability for work-related issues. Finally, we present a critical reflection about the scale's five dimensions.

K E Y   W O R D S
digital competence, digitalization of work, digital cooperation, sales & service, frontline employees, human-computer interaction

10.2478/emj-2025-0019

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Introduction

Digital transformation, defined by the convergence of advanced technologies and the integration of physical and digital systems, has significantly influenced both individual and organizational activities. Prior research highlights that information technology has reshaped how people communicate and work, while also shaping essential competencies such as knowledge, skills, and attitudes (Piwowar-Sulej et al., 2024). In the emergence of the digital era, the rapid integration of transformational and constantly enhancing digital technologies demands new skills and competencies of employees (Atalay et al.,

Süße, T., Kobert, M. & Siderska, J. (2025). Key elements of digital competence in professional sales & service work: Development and evaluation of a self-assessment scale for frontline employees. *Engineering Management in Production and Services, 17*(3), 51-67. doi: 10.2478/emj-2025-0019

2018; Gudanowska et al., 2020; Rollnik-Sadowska et al. 2024). Rapid technological advancements are reshaping service frontlines, creating more complex touchpoints. These evolving interactions place higher expectations on frontline employees to provide a positive customer experience (Xie et. al., 2025). The discussion about digital competence of the work force has gained increasing awareness and is developing towards a novel and important research stream in human-computer interaction (Murawski & Bick, 2017). A main reason for that development can be seen in the fact that digital competence of employees has increasingly been considered as a critical success factor for the digital transformation in and of organizations. Boyaci & Atalay (Atalay et al., 2018), for example, state that employees need to be able to find, process and structure information, solve complex problems, be creative and innovative and communicate and cooperate effectively through digital technologies. These job demands express the shift from a rather technical orientation of so-called digital skills or IT skills towards a much wider perspective of content- and context-related higher-order competencies (Claro et al., 2012). However, when discussing about human actors' competencies, the terms competence and skill are often used interchangeably. In this study we refer to Bassellier et al. (Bassellier et al., 2001) who define competence as an individual's "potential which leads to an effective behavior". Thus, contrary to digital skills that are defined as "the ability to use the computer or other devices such as a smartphone" (Oggero et al., 2020), digital competencies do not only include abilities such as using software or operating a digital device, but integrate a complex set of effective behavioral patterns that are based on "a large variety of complex cognitive, motor, sociological, and emotional abilities, which users need in order to function effectively in digital environments" (Eshet-Alkalai, 2004).

Although, a growing number of instruments to measure digital competencies or skills already exist, most of them remain fragmented or limited to specific domains (Bouwmans et al., 2024), are rather focused on skills than competencies or do not consider the broad range of competencies needed to cope with the range of digitalization demands in human-computer interaction in professional work environments. Furthermore, as Oberländer et al. (Oberländer et al., 2020) state in their literature review about digital competence, empirical based research so far is mainly focused on the educational sector. Thus, frameworks explicitly focusing on professional work beyond education and learning are still very rare.

This article seeks to address this gap in research. Empirical-based development of a digital competence scale is conducted for frontline employees in sales & service work, a work environment that has gained increasing importance during the last decades and is crucial for the shift towards a service-based and co-creative economy. Typical responsibilities of frontline employees are detecting customer needs, obtaining information about competitors, identifying potential resources and capabilities that the organisation can develop, and processing knowledge to innovate (González-González & García-Almeida, 2021). Frontline employees are instrumental in adapting their service to suit the individual customer needs. In high contact services, like financial, healthcare and airlines, they need to deal with every customer differently as the interactions are highly personal and variable in nature. Detailed information about customers and their path to service facilitate frontline employees to adapt the service in an optimal fashion (Motamarri et al., 2017). Thus the job of frontline employees includes a lot of information processing.

So far, digitalization has had significant impact on the work of frontline employees in sales and service work fields (Evans et al., 1999; Temerak et al., 2024). New digital technologies enhanced by latest AI advancements make it, for example, possible to collect, analyze, systematize and structure huge amounts of customer and market data to support customer relationship management, enable selling via digital sales channels as well as facilitate more specific and agile communication with customers and colleagues (Alavi & Habel, 2021). Thus, due to the increasing adaption of information and communication technology the tasks and activities for frontline employees are constantly changing. Capturing and processing data makes it, for example, possible to organize, store and use sales-related knowledge. This demands for appropriate digital competences of frontline workers (Singh et al., 2019). Sales digitalization expands the role of technology by including Internet of Things (IoT), AI agents and digital products and services. Processes, such as customer relationship management, repetitive or straight-by sales and other tasks are increasingly automated. AI-based chatbots, for example, can answer customer questions immediately and with accuracy (Pemer, 2021). Overall, research highlights the potential for digitalization to enhance the capabilities of sales and service and especially frontline employees (González-González & García-Almeida, 2021; Lages & Piercy, 2012; Motamarri et al., 2017; Paluch et al., 2022). A frontline employee's attitude and orientation toward their organizational role is a key factor in determining the quality of service delivered to customers (Jung et al., 2023). In this regard the increasing demand for different skills and competencies for frontline employees is highlighted by recent research

(Guenzi & Nijssen, 2021; Motamarri et al., 2017; Paluch et al., 2022; Pemer, 2021). The skills and competencies outlined, include, among others, proficiency in general computing software and data analytics, the ability to use new technologies to analyze consumer behavior and anticipate purchasing needs, the capability to use advanced digital and social strategies to produce more leads and commercial transactions. Furthermore, frontline workers are expected to accompany the customer during the complete buying process and with the opportunities offered by big data they will also have to learn to organize the information at hand and convert it to real sales while customers are developing more towards co-creators of the final solution (Elhajjar et al., 2024). To effectively perform their roles in a digitalized environment, frontline employees will also have to be able to design, develop and implement digital information systems (Mahlamäki et al., 2020) or to monitor, control or optimize operations to deliver value to customers through Digital-Product Service Systems (Aufreiter et al., 2021). With regards to these development in human-computer interaction in professional sales work the main research question of this article is: What are key dimensions of a not all-encompassing but context-specific scale of digital competence for frontline employees in sales & service work and how can these dimensions be measured?

To answer this research question, the article follows a three-step process. In the first step a set of competencies that are regarded as important for frontline employees is derived conceptually and complemented by context-related empirical research. In the second step empirical data gathered over a period of several years from different domains in the fields of interest is analyzed with the help of exploratory as well as a confirmatory factor analysis. In the third step the resulting digital competence scale derived from confirmatory factor analysis validated by taking into account the other variables measured which are technostress, virtualization of work, space-time flexibility at work and availability for work-related issues.

1. Literature review

1.1. Conceptualizations of digital competence

There are several different conceptualizations of the construct of digital competence. Aznar and Gonzales (Aznar & González, 2010) for example, define digital competence as an individual actor's set of competencies needed for the effective usage of latest information and communication technology to solve problems in non-work and work-related contexts. According to Eshet-Alkalai (Eshet-Alkalai, 2004) digital competence should consist of "reading instructions from graphical displays in user interfaces; using digital reproduction to create new, meaningful materials from existing ones; constructing knowledge from a nonlinear, hypertextual navigation; evaluating the quality and validity of information; and have a mature and realistic understanding of the rules that prevail in the cyberspace". Ferrari et al. (Ferrari, Anusca, 2012) state that the five facets information management, communication in digital environments, content-creation, safety and problem solving build up the digital competence dimensions whereas Calvani et al. (Calvani et al., 2008) refer to technological, cognitive, ethical and integrated capabilities that are needed to cope with digitalization demands. Ilomaki et al (Ilomäki et al., 2016) suggest that digital competence consists of the four dimensions: technical competence; the ability to use digital technologies in a meaningful way, e.g. for working; the ability to evaluate digital technologies critically; and the motivation to participate and commit in the digital culture. The Digital Competence Framework (DigComp) introduced by the EU has gained high attention by research and practice (Carretero Gomez et al., 2017; Vuorikari et al., 2022) as well. This framework contains the five dimensions information and data literacy, communication and collaboration, digital content creation, safety as well as problem solving and focusses on European citizens in general. Recent scales that have first been tested and developed in the education sector already refer to the DigComp framework (Krempkow, 2022). Other works take into consideration similar competencies such as understanding computer use, evaluating, managing, transforming, creating and sharing as well as using information safely and securely (Fraillon et al., 2014; Hatlevik & Hatlevik, 2018). From the above considerations, it can be followed that a digital competence scale can be considered as a complex and multidimensional construct consisting of several sub-dimensions.

However, the majority of recent literature on digital competence is focused on the field of education and mostly consist of self-assessment questionnaires that aim at assessing students' or teachers' digital information searching, content creation, communication, problem solving as well as technical skills (Budai et al., 2023; Miltuze & Litiņa, 2021; Parra-Camacho et al., 2023; Pettersson, 2018; Reisoğlu, 2022; Zhao et al., 2021). One scale that goes beyond the education sector stems from Van Laar et al. (van Laar et al., 2018, 2020). It is an

Tab. 1. Conceptualizations of digital competence from literature

Author(s)	Conceptualization
(Eshet-Alkalai, 2004)	reading instructions from graphical displays in user interfaces; using digital reproduction to create new, meaningful materials from existing ones; constructing knowledge from a nonlinear, hypertextual navigation; evaluating the quality and validity of information; have a mature and realistic understanding of the rules that prevail in the cyberspace
(Ferrari, Anusca, 2012)	information management, communication in digital environments, content-creation, safety and problem solving
(Fraillon et al., 2014)	technical competence; the ability to use digital technologies in a meaningful way, e.g. for working; the ability to evaluate digital technologies critically; and the motivation to participate and commit in the digital culture
(Fraillon et al., 2014)	understanding computer use, evaluating, managing, transforming, creating and sharing as well as using information safely and securely
(van Laar et al., 2018, 2020)	information management, communication, collaboration, critical thinking, creativity and problem solving
(Oberländer et al., 2020)	25 distinct dimensions of digital competences, starting with the ability of handling the functionalities of hard- and software, over programming and information processing skills, communication and collaboration competencies up to security, law and ethics as well as skills to train and educate others

extensive 21st century digital skill framework validated for creative industries and consisting of the dimensions information management, communication, collaboration, critical thinking, creativity and problem solving. Another scale that is based on the DigComp framework is a self-concept scale consisting of 25 items and the five factors communicate, process and store, generate content, safe application and solve problems that was constructed and validated on a large sample including employees from different branches (Schauffel et al., 2021). Overall, an extensive literature review from Oberländer et al. (Oberländer et al., 2020) on digital competence, which also takes into consideration the EU's DigComp framework as well as the framework developed by Van Laar et al. comes up with a set of 25 distinct dimensions of digital competence, starting with the ability of handling the functionalities of hard- and software, over programming and information processing skills, communication and collaboration competencies up to security, law and ethics as well as skills to train and educate others. Another conclusion made by the literature review conducdet by Oberländer et al. (Oberländer et al., 2020) is that there is still a lack of scientific research on this topic, especially when it comes to adults in professional work contexts. Table 1 provides a summary of influential conceptualization of the concept of digital competence.

1.2. Digital competence for frontline employees in professional sales & service work

By taking into consideration the conceptualizations provided by the literature summarized above and specific facets of competence relevant for sales & service-oriented working environments, Author et al.

Tab. 2. Digital competence dimensions for frontline employees in sales & service

Dimension	Description
(1) Effective usage of technologies & tools	Ability of accessing the functionalities of technologies and tools effectively; basic understanding about the interrelationships or interfaces between various tools; recognizing or deal with upcoming problems
(2) Farsighted data & information handling	Awareness of potential security and privacy risks while working with sensitive data and information from people as well as organizations.
(3) Critical information evaluation & handling	Reflecting about the quality of information; evaluating various sources of information, e. g. based on their reliability; identifying appropriate information.
(4) Sustained cooperation & communication	providing mutual support; communicating constructively and effectively; sharing expertise and innovative knowledge; acting cooperatively
(5) integrative knowledge generation	Integrating knowledge from various sources during a collective and discursive process in order to contribute to knowledge innovation.
(6) co-creative problem-solving	development of solutions in work-related settings with the help of applying digital tools, digitalized knowledge and other digital resources in an effective manner in closed interaction with other actors

(Author et al., 2018) introduced an initial digital competence framework for stakeholders in Product-Service Systems consisting of ten self-assessment items. This specific set of items is grouped into three sub-dimensions: confident handling of digital resources to collect relevant information, problem-oriented usage of digital resources for own and collective problem-solving processes as well as critical evaluation of information from digital sources. In a later contribution Authors built on the above findings and extended the initial three dimensional model towards a six-dimensional digital competence framework. Based on a qualitative analysis on expert interviews among frontline employees during the digital transformation of an organization's sales unit a six-dimensional framework has been developed represented in Table 2. These dimensions comprise of (1) effective usage of technologies & tools, (2) farsighted data & information handling, (3) critical information evaluation & handling, (4) sustained cooperation & communication (4), (5) integrative knowledge generation and (6) co-creative problem-solving (Authors). Due to the explicit focus of this study and the six dimensions of digital competence revealed we take up this systematization as the basis for the further development of a self-assessment scale of digital competence that relates to frontline employees in sales & service work.

1.3. Measurements

The items to measure the construct presented in Table 2 were developed or created taking into consideration existing literature on digital competence and specific competence demands in professional sales & service work. The digital competence construct for jobs in the field of sales & service differs from other constructs in that the dimensions specifically focus on co-creative, knowledge-intense and highly context-related tasks. Thus, the items mainly include the confident and critical searching, sensing, recombining and creating information and knowledge as well as the communication of this information through digital tools. It is a self-assessment scale, consisting of thirty items that are measured at the individual level with a seven-point Likert-type scale (Strongly Disagree; Disagree; Slightly Disagree; Neutral; Slightly Agree; Agree; Strongly Agree). Furthermore, multi-item measurement was used as the combination of multiple items prevents random error in the items and therefore increases the reliability (Sarstedt & Wilczynski, 2009). Moreover, multiple items cover a larger number of distinct construct facets and therefore increase construct validity (Wanous et al., 1997).

2. Research methods

In this section, we refine our conceptually derived digital competence scale illustrated in Table 2 and Table 3 by applying statistical methods. We collect quantitative data by applying the questionnaire as it is shown by Table 3.

2.1. Sample

Data was collected by five online surveys between 2017 and 2023 and resulted in five samples summarized by Table 4.

By aggregating all data from the five samples we reach a total sample of N=1283. In the following table (Table 5) descriptive statistics are illustrated for the aggregated sample.

From the total sample we drew a random subsample of 30% with N=385 as a construction sample for performing an exploratory factor analysis (EFA). On the remaining sample (N = 898), we perform a confirmatory factor analysis (CFA) as we explain below. We perform EFA with SPSS 28 and CFA with AMOS.

2.2. Exploratory Factor Analysis (EFA)

The EFA is a multivariate statistical method that was first applied by Spearman (1904). Today, this method is commonly used for the development and validation of measurements in social sciences (Fabrigar & Wegener, 2011). We perform the EFA on the construction sample (N=385).

First, we test whether our data is appropriate for performing an EFA via the Bartlett's test for sphericity and the Kaiser-Meyer-Olkin (KMO) measure (Fabrigar & Wegener, 2011). The Bartlett's test tests the null hypothesis that the correlation matrix of items is an identity matrix to ensure that there are some relationships between items or group of items. Thus, the Bartlett's test should be significant. The Kaiser-Meyer-Olkin measure is a measure of the proportion of variance among items that might be common in variance. KMO values between 0,8 and 1 indicate that the sample is adequate for EFA. In our case, the Bartlett's test is significant with $Chi^2(300)=3462,748$ and $p < 0.001$ and the KMO value amounts to .894. Since both tests indicate that the sample is adequate for EFA, we proceed with the analysis.

We perform a Varimax rotation and use a Weighted Leasts Squares (WLS) Estimator. To determine, whether the five-dimensional structure from sec-

Tab. 3. Measures of digital competence for frontline employees in sales & service

Dimensions	Items	No
(1) Effective usage of technologies and tools	I can confidently handle the functions and opportunities of digital platforms, websites or other digital tools.	1
	I easily find the relevant information I need by exploring the internet	2
	I'm well able to search effectively for relevant information online.	3
	The internet helps me to keep up with changes within the organization and beyond.	4
	In order to question dominant perspectives or the status quo I also use online tools to express my opinion.	5
(2) Farsighted data & information handling	I constantly evaluate the information provided by the internet or by digital media.	6
	I obey rules and regulations in online environments even when no one is watching.	7
	I use online tools to share my expertise or my knowledge with others. (-)	8
(3) Critical information evaluation & processing	I critically reflect about digital information provided online.	9
	I critically compare digital information from various providers or sources.	10
	I critically evaluate the authenticity of sources of digital information.	11
(4) Sustained cooperation & communication	I am careful about how I say things online so they don't come across the wrong way.	12
	If I disagree with people online, I watch my language so it doesn't come across as mean.	13
	I think about making sure that things I say and post online will not be something I regret later.	14
	I take steps to try to prevent problems with other workers during online collaboration.	15
	I try to avoid creating problems for online coworkers or colleagues.	16
	I help others who have been absent to participate in online cooperation.	17
	I help orient new people in online environments even though it is not required.	18
	I attend online meetings that are not mandatory, but are considered important.	19
(5) Integrative knowledge generation	I create my own classifications of digital information in order to combine information in a problem-specific manner.	20
	I structure complex tasks and problems with the help of digital tools and methods.	21
	I can develop new problem solutions with the help of information provided by the internet	22
	I recombine information from various digital sources to solve complex problems.	23
	I use online information and digital tools particularly for my own development and improvement.	24
	In order to keep up with latest trends I read online newsfeeds.	25
(6) Co-creative problem-solving	In order to solve novel problems I often use the information provided by online resources and digital media.	26
	I'm well able to use digital information to solve individual problems.	27
	I'm well able to use digital information to solve problems in teams.	28
	I'm well able to use digital information from online platforms in combination with other sources of information (e.g. books).	29
	I use online tools to improve the work context or professional environment in some way.	30

Tab. 4. Samples used for EFA and CFA

Sample 1 N=128	Data was collected in 2017 and 2018. Respondents were Bachelor and Master students from Management and Engineering studies in Germany taking part in a learning laboratory designed as a digital sales & service business ecosystem simulating an actual work environment of frontline employees.
Sample 2 N=174	Data was collected in 2018. Respondents were students in Finland and France taking part in a learning laboratory designed as a digital sales & service business ecosystem simulating an actual work environment of frontline employees.
Sample 3 N=145	Data was collected in 2019. Respondents were professionals from various sectors and industries working as frontline employees and studying part-time in Germany.
Sample 4 N=633	Data was collected by an open online survey in Germany, which took place in the period from June 16th 2020 to August 31st 2020, during the COVD-19 pandemic. Respondents were professionals from various sectors of industry working as frontline employees in the broader area of sales & services and studying part-time.
Sample 5 N=203	Data was collected in the end of 2022 and the beginning of 2023. Respondents were frontline employees from various knowledge related industry sectors.

Tab. 5. Descriptive statistics

Gender	**Male**	**Female**	**Diverse**	**Not specified**
Sample 1	65 / 50.8 %	63 / 49.2 %	-	-
Sample 2	80 / 46 %	92 / 52.9 %	-	2 / 1.1 %
Sample 3	88 / 60.7%	57 / 39.3 %	-	-
Sample 4	174 /27.5%	459 /72.5%	-	-
Sample 5	158 / 77.8%	39 /19.2%	2 / 1%	4 /2%
Aggregated	565 /44%	710 / 55.4%	2 /0.1%	6 /0.5%

Age (years)	18 - 27	28 - 37	38 - 47	48 - 57	>57	Not specified
Sample 1	118 /92.2 %	10 /7.8 %	-	-	-	-
Sample 2	157 /90.2 %	11 / 6.4 %	6 / 3.4 %	-	-	-
Sample 3	129 / 89%	15 / 10.3 %	1 / 0.7 %	-	-	-
Sample 4	436 /68.9 %	134 /21.2 %	34 / 5.4 %	21 / 3.3 %	-	8 / 1.3 %
Sample 5	92 /45.3%	41 /20.2%	27 /13.3%	24 /11.8%	19 /9.4%	-
Aggregated	932 / 72.6%	211 / 16.4%	68 /5.3 %	45 /3.5%	19 /1.5%	8 / 6.2%

Education	High school diploma	Apprentice-ship	Master craftsman	Bachelor	Master	Other
Sample 1	94 / 73.4 %	34 / 26.6 %	-	-	-	-
Sample 2	137 /78.7 %	37 / 21.3 %	-	-	-	-

Sample 3	104 / 71.7%	41 / 28.3%	-	-	-	-
Sample 4	96 / 15.2 %	382 /60.3 %	27 / 4.3 %	32 / 5.1%	12 / 1.9%	84 / 13.3 %
Sample 5	75 / 36.9%	56 /27.6%	8 / 3.9%	28 / 13.8%	28 /13.8%	8 / 3.9%
Aggregated	506 / 39.4%	550 / 42.9%	35 / 2.7%	60 / 4.7%	40 /3.1%	92 / 7.2 %

Work experience (years)	0	< 2	2 - 5	> 5
Sample 1	53 / 41.4 %	34 / 26.6 %	12 / 9.4 %	29 / 22.6 %
Sample 2	83 / 47.7 %	60 / 34.5 %	10 / 5.7 %	21 / 12.1 %
Sample 3	18 / 12.4%	93 / 64.1%	21 / 14.5 %	13 / 9%
Sample 4	56 /8.8%	39 / 6.2%	231 / 36.5%	307 /48.5%
Sample 5	6 / 3%	12 /5.9%	57 /28.1%	128 /63.1%
Aggregated	216 / 16.8%	238 / 18.6%	331 / 25.8%	498 /38.8 %

Industry sector	Construction, Architecture	Services	Engineering, Technology	Health	IT, Computer	Arts, Culture, Design	Agriculture, Nature	Media	Sciences	Manufacturing	Pedagogics	Transport, Logistics	Business, Administration	Not specified
Samp. 1	-	-	-	-	-	-	-	-	-	-	-	-	-	128/ 100%
Samp. 2	-	-	-	-	-	-	-	-	-	-	-	-	-	174/ 100%
Samp. 3	-	-	-	-	-	-	-	-	-	-	-	-	-	145 /

tion in Table 3 is supported numerically, we perform a parallel analysis, which reveals a structure consisting of five factors to be suitable. This supports our conceptual considerations. Only items significantly correlated with at least two other items and with factor loadings above 0,33 are included into the analysis. Thus, for the first round we drop the items 5, 16, 17, 18 and 19. We next exclude the items 4, 20 and 30 since they show loadings of above 0.33 on more than one factor. We run another EFA with the remaining 22 items. The result consists of five factors with factor 1 consisting of items 1, 2 and 3; factor 2 included items 6, 9, 10, 11 and 25; factor 3 the items 12, 13, 14, 7 and 15; factor 4 the items 21, 22, 23, 24; and factor 5 included the items 26, 27, 28 and 29. The total variance explained amounts to 48,17 %. The results of the EFA are illustrated in Table 6.

2.3. Reliability

As a next step, we analyze the reliability of the five factors on the validation sample (N=898). Cronbach's Alpha (α) (Cronbach, 1951) is a widely used measure for construct's reliability. Usually, a value of $\alpha > .7$ is seen as an indicator for a good reliability of a scale (Taber, 2018). In our sample, $\alpha > 0.7$ for all five factors (see Table 6). However, for factor 2 and factor 5, the reliability can be increased by dropping item 25 and item 26 respectively. The final α values are illustrated in Table 8.

2.4. Confirmatory Factor Analysis (CFA)

In order to confirm the five factor structure obtained through EFA, we performed a confirmatory factor analysis (CFA) on the validation sample (N=898), after dropping item 25 for factor 2 and item 26 for factor 5. Though our data are not normally distributed, maximum likelihood (ML) estimator seems to be appropriate since the data set is reasonably large (Hoyle, 2000). To determine goodness of fit, there are a lot of fit indices, mentioned in the literature.

First of all, there are absolute fit indexes such as the Goodness of Fit Index (GFI), the Adjusted Goodness of Fit Index (AGFI), which takes into account the degrees of freedom as well as the root mean square error of approximation (RMSEA) (Hoyle, 2000). GFI and AGFI range from zero to 1.0, whereas values greater than .90 are viewed as indicative of good fit (Hair et al., 2006). The minimum value of RMSEA is zero, a value it will take when a model exactly reproduces a set of observed data. A value of .05 indicates a close fit, .08 indicates a marginal fit, and .10 indicates a poor fit (Browne, 1993; Fabrigar et al., 1999). Another well-known value is Chi²/df, where df represents the degrees of freedom. However, there is no consensus about a good value for Chi²/df. The recommendations vary from 3, 2 or less to 5 (Arbuckle, 2005). Another well-known parameter is the (Standardized) Root Mean Squared Residual (S)RMR, which is a measure of the average unexplained covariances in a model. A model is considered to have a good fit, if the value for (S)RMR is less than 0.05 (Hair et al., 2006).

Furthermore, there are also comparative fit indexes, which are used to compare the fit of a proposed model with the fit of a strategically chosen baseline model (Bentler & Bonett, 1980). The standard baseline model is referred to as the null model or independence model. The commonly used comparative fit index is the CFI, which like GFI and AGFI varies between 0 and 1 and indexes the relative reduction in lack of fit of a proposed model over the null model. Values of .90 or higher indicate an acceptable fit (Hu & Bentler, 1995). Often, it is also recommended to use the Tucker-Lewis Index (TLI), which also has to be greater than 0,9 to show an acceptable fit (Jahn, 2007). The index values for the present model are illustrated in Table 7.

All values apart from RMR and SRMR indicate a good fit. Since RMR is very close to .05 and SRMR is equal to 0.05, we can conclude that our model has an acceptable or even good fit (Browne, 1993; Fabrigar et al., 1999).

3. Research Results

3.1. Digital Competence framework for frontline employees in sales & service work

In Table 8 the resulting construct consisting of the five factors confident (1) effective usage of technologies and tools, (2) farsighted & critical information handling, (3) sustained cooperation & communication, (4) integrative knowledge generation, (5) co-creative problem solving is presented.

The facet Effective usage of technologies and tools reflects, on the one hand, the ability of handling the functionalities of digital tools confidently on the other hand it focuses on fast and effective information detection and handling, which is formerly important as the work of frontline employees gets increasingly knowledge intense. Compared to the construct in table 3 that was derived conceptually and through qualitative methods, in the construct that is derived numerically the facet does not include item 4 and item 5. Farsighted & critical information handling is concerned with the capability of being reflective and critical with information provided by digital media or other digital sources. It also includes the ability to compare different sources and to evaluate those due to their credibility. This competence is often seen to be important for people in the digital age and especially for those who are concerned with information gathering and processing tasks. The factor combines the two factors Farsighted data & information handling and

Tab. 6. Results of EFA

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Including items (no)	1, 2, 3	6, 9, 10, 11, 25	12, 13, 14, 7, 15	21, 22, 23, 24	26, 27, 28, 29
Variance explained (%)	8,62	10,51	10,21	8,87	9,96
Reliability (α)	.800	.796	.771	.810	.779

Tab. 7. Fit indices for CFA

GFI	AGFI	RMSEA	RMR	SRMR	Chi²/df	CFI	TLI
.932	.910	.059	.057	.050	3.21	.925	.910

Tab. 8. Digital competence framework: final result

	Item	Factor loadings				
	(1) Effective usage of technologies and tools	1	2	3	4	5
1	I can confidently handle the functions and opportunities of digital platforms, websites or other digital tools.	.676				
2	I easily find the relevant information I need by exploring the internet	.862				
3	I'm well able to search effectively for relevant information online.	.531				
	(2) Farsighted & critical information handling					
6	I constantly evaluate the information provided by the internet or by digital media.		.549			
9	I critically reflect about digital information provided online.		.755			
10	I critically compare digital information from various providers or sources.		.650			
11	I critically evaluate the authenticity of sources of digital information.		.732			
	(3) Sustained cooperation & communication					
12	I am careful about how I say things online so they don't come across the wrong way.			.483		
13	If I disagree with people online, I watch my language so it doesn't come across as mean.			.723		
14	I think about making sure that things I say and post online will not be something I regret later.			.670		
7	I obey rules and regulations in online environments even when no one is watching.			.601		
15	I take steps to try to prevent problems with other workers during online collaboration.			.508		
	(4) Integrative knowledge generation					
21	I structure complex information and problems with the help of digital tools and methods.				.473	
22	I can develop new problem solutions with the help of information provided by the internet				.691	
23	I recombine information from various digital sources to solve complex problems.				.613	
24	I use online information and digital tools particularly for my own development and improvement.				.562	
	(5) Co-creative problem solving					
27	I'm well able to use digital information to solve individual problems.					.749
28	I'm well able to use digital information to solve problems in teams.					.797
29	I'm well able to use digital information in combination with other sources of information (e.g. books).					.458
	Percentage of Variance explained (sum: 50.1 %)	8.5	11.0	11.6	10.5	8.5
	Mean value	6.05	5.25	5.66	5.31	5.37
	Standard deviation	.897	1.06	0.92	0.96	0.97
	Cronbach's alpha	.800	.816	.771	.810	.794

Critical information evaluation & processing from table 3 whereas items 7 and 8 are missing in the final result. The next factor, Sustained cooperation & communication consists of specific communication as well as cooperation in digital environments. These include, for example, the capability of being careful with things one says or writes online since these information is not revocable on the one hand and on the other hand one can be easier misunderstood in e.g. Online-Chats. Compared to the construct presented in table 3 this factor does not include items 16 - 19 but item 7 that was assigned to factor 2 in table 3. Integrative knowledge generation deals with the ability of structuring, recombining and using digital information for solving complex tasks as well as for one's own improvement. Compared to table 3, this facet does not include item 20. Last but not least, Co-creative problem solving consists of capabilities such as the use of digital information for solving individual as well as problems in teams but also the ability to combine digital information with other offline information sources. Here item 26 and item 30 are missing compared to the solution in Table 3.

3.2 Scale Validity

To validate the scale by means of construct validity we formulated hypotheses and tested them by employing correlational designs and mean value comparisons.

H1: There is a significant negative correlation between digital competences and technostress.

We test this hypothesis by using sample 5 (N=203). Stress that results from working in digitalized work environments is called technostress (Dragano & Lunau, 2020; Salanova et al., 2014; Wang et al., 2022). As digital competencies are intended to enable individuals to cope better with digital job demands, we argue that there is a negative relationship between technostress and digital competencies. We use the technostress questionnaire (Ragu-Nathan et al., 2008; Westermann, 2017), which consists of the three factors techno-overload, techno-invasion and techno-complexity to measure stress. Techno-overload is concerned with the higher workload that stems from constantly having to deal and get familiar with novel and unknown technologies. Techno-invasion refers to the greater availability resulting from the use of digital technologies and techno-complexity addresses the technical complexity of digital tools and the individual's inability to deal with it properly.

As can be seen in Table 9 confident handling of digital resources as well as effective information handling & generation are significantly negatively correlated with all three facets of technostress. For techno-complexity the correlation coefficient is even around -0.5. Techno-complexity is significantly negatively correlated to all facets of digital competencies except for sustained cooperation & communication. Overall, the results presented in Table 9 partly support hypothesis 1 (H1).

H2: Workers who maintained working virtually beyond the first COVID-19 related lockdown rated own digital competencies to be on average significantly higher than those who only experienced a minimal or short increase of virtual work during the lockdown.

To test hypothesis H2 we use the COVID-19 related sample 4 with N=633. Here, we distinguish between three clusters of workers depending on their virtual working hours before, during and after the first COVID-19 related lockdown in Germany:

Cluster 1: minimal exceptional virtualization

Cluster 2: substantial exceptional virtualization

Cluster 3: substantial sustainable virtualization

We argue that workers who belong to cluster 3, and thus have had more experience with virtual work than workers who experienced a minimal or short increase of virtual work, rate their digital competences to be averagely higher than those in cluster 1 or cluster 2. We use the one-way ANOVA to test the hypotheses. The results are illustrated in Table 11.

As can be seen in Table 11, the ANOVA is significant for the two competencies farsighted & critical information handling as well as co-creative problem solving. The effect-size estimator η^2 indicates that the magnitude of the mean differences is rather small ($.01 \leq \eta^2 \leq .06$) which can be seen as an indicator for a rather small effect (Cohen, 1988; Okada, 2013). This partly supports hypothesis H2.

H3: There is a significant positive correlation between space-time flexibility and digital competencies.

This hypothesis is tested on sample 3 (N=145). Space-time flexibility refers to time and location flexibility at work. The five item scale is concerned with employees' possibility of working independently of time

Tab. 9. Correlation coefficients between technostress and digital competencies

	(1) Effective usage of technologies and tools	(2) Farsighted & critical information handling	(3) Sustained cooperation & communication	(4) Integrative knowledge generation	(5) Co-creative problem solving
Techno-overload	-.276**	--	--	--	-.202**
Techno-complexity	-.544**	-.301*	--	-.311**	-.433**
Techno-invasion	-.272**	--	--	--	-.272**

Tab. 10. Virtualization clusters

	Number	%
Cluster 1	182	37.3
Cluster 2	179	36.7
Cluster 3	127	26.0

Tab. 11. ANOVA Results

	Cluster 1	Cluster 2	Cluster 3	F	df	Significance	η^2
(1) effective usage of technologies and tools Mean SD	6.289a 0.694	6.301a 0.663	6.412a 0.598	1.432	2	0.239	0.01
(2) farsighted & critical information handling Mean SD	5.198a 1.011	5.334a 0.912	5.640b 0.910	8.170	2	< 0.001	0.03
(3) sustained cooperation & communication Mean SD	5.746a 0.861	5.823a 0.797	5.916a 0.741	1.668	2	0.190	0.01
(4) integrative knowledge generation Mean SD	5.397a 0.863	5.445a 0.882	5.562a 0.883	1.337	2	0.264	0.01
(5) co-creative problem solving Mean SD	5.353a 1.586	5.497a 1.493	5.785b 1.395	10.138	2	< 0.001	0.04

Note: a,b Mean values that don't share the same subscript within one row are significantly different (significance calculated with the help of post-hoc Tests).

and space constraints and is measured on a 7-point Likert scale (Poethke et al., 2019). We argue that there is a positive relationship between space-time flexibility and digital competencies.

As one can see in Table 12 hypothesis H3 is supported.

H4: There is a significant positive correlation between the digital competence facet sustained cooperation & communication and availability.

This hypothesis is tested on sample 3 (N=145). Availability is concerned with workers' readiness of being available through digital tools during non-official working hours. It is measured by five items that deal with the extent to which a person can be reached by cell phones, e-mail, etc. while being e.g. on vacation or outside working hours (Poethke et al., 2019). Availability is measured on a 7 point Likert scale. We argue, that there is a positive relationship between availability beyond ones working hours and digital communication competencies.

The correlation coefficient between sustained cooperation & communication and availability amounts to $r = .221$, $p = .011$. This supports hypothesis H4.

4. Discussion of the results

The further advancements in digitalization in professional work environments create new competence demands for workers that need further specification and validation. Instruments or scales for measuring digital competence are less developed so that even researchers are forced to follow rather pragmatic approaches for conducting empirical investigations (Bartolomé et al., 2022; Golz et al., 2021). One of the very few but more comprehensive and widely recognized approaches of gathering digital competence of workers has been introduced by van Laar et al. (2018, 2020) who developed an extensive 21st century digital skill framework for creative industries. However, the authors point out some peculiarities of their framework as it consists of frequency scales instead of usually used self-assessment scales and that the approach refers to a wider range of different competencies and skills not having a clear focus on digital competence as such which results in a comparably long measurement instrument. In general, it can be stated that the individual level of workers' competence as the unit of analysis is still underrepresented in scientific writing about digital transformation and sustainable digital enhancements in organizations. This article is one among the first introducing an empirical-based validation of a self-assessment scale of digital competence for frontline employees in sales & service (N=1,283). With respect to the guided research question "What are key dimensions of a not all-encompassing but context-specific scale of digital competence for frontline employees in sales & service work and how can these dimensions be measured?" we introduced

Tab. 12. Correlation coefficients between digital competencies and flexibility

	(1) EFFECTIVE USAGE OF TECHNOLOGIES AND TOOLS	(2) FARSIGHTED & CRITICAL INFORMATION HANDLING	(3) SUSTAINED COOPERATION & COMMUNICATION	(4) INTEGRATIVE KNOWLEDGE GENERATION	(5) CO-CREATIVE PROBLEM SOLVING
Space-time flexibility	.272**	.256**	.305**	.332**	.262**

*: p<0.05; **: p<0.005

Tab. 13. Correlation coefficients between digital competencies and availability

	(1) EFFECTIVE USAGE OF TECHNOLOGIES AND TOOLS	(2) FARSIGHTED & CRITICAL INFORMATION HANDLING	(3) SUSTAINED COOPERATION & COMMUNICATION	(4) INTEGRATIVE KNOWLEDGE GENERATION	(5) CO-CREATIVE PROBLEM SOLVING
Availability	.143	.124	.211*	-.017	.149

*: p<0.05; **: p<0.005

a five-dimensional scale of digital competence consisting of (1) effective usage of technologies and tools, (2) farsighted & critical information handling, (3) sustained cooperation & communication, (4) integrative knowledge generation, and (5) co-creative problem solving. As statistical analysis among various sub samples revealed, this 19 item scale (Appendix A) shows good reliability and internal consistency. Regarding validation, we referred to the variable of employee related technostress as well as the context related variable of virtualization and digitalization of the work environment. As expected, the results of the validation with technostress show highly significant negative correlations with four of the five dimensions of digital competence. This is in line with state-of-the art research arguing that specific digital competencies may equip employees to better cope with technology-induced stress. However, further empirical analysis is needed in that regard. The contextual variable of space-time flexibility, which is a typical characteristic for frontline workers, shows highly significant positive correlations for all five dimensions of the digital competence scale introduced. This can mean, that e.g. due to selective processes in the work environment or ongoing workplace learning frontline workers show higher degrees of digital competence in the five dimensions introduced. However, as the construct of technostress the contextual variables do not allow interpretation of causalities based on the empirical data analyzed in this article.

Nevertheless, we argue that based on the five dimensions of digital competence, which we regard as a not all-encompassing but context-related validation of specific competencies we make a substantial contribution for reducing the scientific-practice gap when it comes to work-related evaluation of digital competencies among employees (2020). The present article might be considered as a starting point to close this gap. Based on the validated digital competence scale for frontline employees in sales & service we provide more specific knowledge about key competencies employees may need to interact more effectively with modern digital tools and technologies like generative AI and other highly knowledge intensive systems. Within the context of professional work, we except that not all of the five dimensions of digital competence we derived will be equally important as this might be the case for rather basic competencies. We find it more likely that based on various job roles and contextual demands there will be distinct configurations consisting of a set of complementary competence levels with regards to each of the five dimensions. However, much more empirical knowledge is required in that area, e.g. to enable and support more advanced competence management for human-computer interaction in professional work.

From our point of view future research in the field of digital competence should consider more explicitly the causalities between different variables, e.g. focusing on the question about how different digital competencies affect efficiency, effectivity as well as adaptability, sustainability or innovative output of human-computer interaction at work. With a specific focus on digitalization in the professional filed of frontline sales & service workers further investigations about the impact of employee's digital competence on the short-, mid- and long-term success of sustainable sales success, customer satisfaction or economic growth might be of interest. Also, the question about how digital leadership may foster digital competence development in professional work environments is considered as highly relevant in organizations. Other aspects we regard as highly important are how digital competence can be defined and measured on a group and team level, especially when considering virtual teams including human-agent teaming as well as how the perception of social isolation in a highly digitalized work and society may be addressed by digital competence.

In summary the objective of this research article is to enable similar and other research initiatives by providing one of the first validated scale of digital competence which is clearly not all-encompassing, but an entrance point into a more systematic understanding in future research about the causes and effects of digital competence in professional human-computer interaction. The final questionnaire of the validated scale can be found in Appendix A.

Conclusions

This study advances the discourse on digital competence in professional contexts by introducing one of the first empirically validated self-assessment instruments specifically designed for frontline employees in sales and service. Drawing on existing conceptual frameworks, we developed a five-dimensional model encompassing proficient use of technologies and tools, anticipatory and critical information management, sustained collaboration and communication, integrative knowledge creation, and co-creative problem solving. The resulting scale exhibits strong reliability and internal consistency, providing a context-sensitive means of assessing digital competence at the individual level. This study offers an empirically substantiated starting point for more systematic inquiries into digital competence within professional human–computer interaction. By introducing a validated and contextually sensitive measurement scale, it establishes a foundation for advancing both scholarly research and organizational competence management, with the aim of preparing employees for work environments that are becoming progressively more digitalized and knowledge-intensive.

The validation analyses demonstrated that higher levels of digital competence are significantly associated with lower levels of technostress, thereby reinforcing the proposition that advanced digital skills equip employees to manage technology-related demands more effectively. Furthermore, the positive associations with contextual factors such as space–time flexibility suggest that frontline employees may enhance their competence through experiential workplace learning and adaptation to increasingly digitalized environments. Although causal inferences cannot be drawn at this stage, these findings underscore the scale's practical utility in narrowing the divide between scholarly research and organizational practice.

The presented digital competence self-assessment scale is considering the increasing relevance of frontline work in sales & service in the era of digitalization. However, a task for future studies is to test and respectively extend the instrument with respect to a more specific set of distinct work systems. Another aspect that has to be pointed at is that the mean values for the presented sample are relatively high which could be explained by the fact that the majority of people in our sample is working in highly-digitalized environments and has an academic background. In addition, more than 90 % of the respondents in the sample are between 18 and 37 years old (see Table 5). This means that a majority of people in our sample can be allocated to the so-called "digital generation". Furthermore, other studies have also revealed that self-assessment scales are more likely to produce higher mean values. Additional empirical investigations with a different and extended sample structure are planned as one of the next important steps to compare and evaluate the presented findings. One expected outcome of such studies could be that the manifestation of distinct competencies could be different when comparing industries, job roles, socio-demographic factors, latest technologies in the field of artificial intelligence or various implementations of the new work approach.

Disclosure of interest

The authors declare that they have no relevant or material financial interests that relate to the research described in this paper.

Funding information

Funded by Hochschule Bielefeld - University of Applied Sciences and Arts. This paper is funded in the framework of the work No. WZ/WIZ-INZ/3/2025 at the Bialystok University of Technology.

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Appendix A

The use and application of digital technologies in your everyday working life

The following questions are dedicated to your personal use of digital tools and technologies during daily work. You will find a list of statements on the use and application of digital tools and technologies. Please assess the extent to which each statement applies to you personally. In your assessment, please select on a scale from 1 = "strongly disagree" to 7 = "strongly agree".

		1	2	3	4	5	6	7
(1) Effective usage of technologies and tools	I can confidently handle the functions and opportunities of digital platforms, websites or other digital tools.							
	I easily find the relevant information I need by exploring the internet							
	I'm well able to search effectively for relevant information online.							
(2) Farsighted & critical information handling	I constantly evaluate the information provided by the internet or by digital media.							
	I critically reflect about digital information provided online.							
	I critically compare digital information from various providers or sources.							
	I critically evaluate the authenticity of sources of digital information.							
(3) Sustained cooperation & communication	I am careful about how I say things online so they don't come across the wrong way.							
	If I disagree with people online, I watch my language so it doesn't come across as mean.							
	I think about making sure that things I say and post online will not be something I regret later.							
	I obey rules and regulations in online environments even when no one is watching.							
	I take steps to try to prevent problems with other workers during online collaboration.							
(4) Integrative knowledge generation	I structure complex information and problems with the help of digital tools and methods.							
	I can develop new problem solutions with the help of information provided by the internet							
	I recombine information from various digital sources to solve complex problems.							
	I use online information and digital tools particularly for my own development and improvement.							
(5) Co-creative problem solving	I'm well able to use digital information to solve individual problems.							
	I'm well able to use digital information to solve problems in teams.							
	I'm well able to use digital information in combination with other sources of information (e.g. books).							