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## Digital Competences of Prospective Engineers and Science Teachers: A Latent Profile and Correspondence Analysis

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### Abstract

In the light of ubiquitous information and communication technologies (ICT) it is essential for everyone to be digitally competent. This is particularly true for prospective engineers and teachers since their jobs play an important role in shaping our common future. We assessed engineering and science teacher students' (n=180) digital competences at two higher education institutions in Germany using the DigComp framework. Applying a group comparison using *t*-Test analysis we found no differences in the level of digital competences. However, the subsequent latent profile analysis followed by correspondence analysis revealed that high digital competences correspond with a frequent use of various ICT, supporting the theory of the importance of implicit learning. Secondly, the data points towards a reproduction of the patterns of the digital divide showing the influence of socio-economic background and gender on the expression of digital competences. Recommendations for agents (student advisory services, companies, etc.) that wish to support and improve students' digital competences are incorporated in the conclusions.

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### Introduction

Digital technologies play an increasingly central role in the lives of citizens worldwide and they are essential to communicate, participate and work in contemporary society (Seeber & Seifried, 2019). Furthermore, technological advancements and the increased availability of ICT resources have changed traditional learning environments: new forms of appropriation, reception, creation and the transmission of experiences and knowledge arise, boundaries between formal, non-formal and informal learning become blurred (Siddiq & Scherer, 2019). A vast body of empirical research underlines the importance that education needs to respond to these changes (Hu, Gong, Lai, & Leung, 2018; Balsmeier & Woerter, 2019; Huang, Henfridsson, Liu, & Newell, 2017; Makarova, Ldokova, & Egorova, 2021).

Consequently, countries all over the globe have installed strategies to train teachers and students towards a competent and responsible handling of ICT. For example, actions have been taken to increase access to ICT resources (Newly & Veugelers, 2009), to adapt engineering and vocational education towards challenges and

demands related to industry 4.0 (Schulze Heuling & Wild, 2021), to facilitating the development of teachers' technological pedagogical content knowledge (Tondeur et al., 2012; Popat & Starkey, 2019), and to integrating ICT literacy in national school curricula (Claro et al., 2012; NDET 2012). However, a large body of research identifies a gap in applying and teaching digital competences in curricular domains such as mathematics, reading, and science (Binkley et al., 2012; Siddiq et al., 2016). While university students are often expected to possess digital skills (Leahy & Dolan, 2010), many of them only possess a limited skill set when entering university (Verhoeven, Heerweg, & De Wit, 2016). Deeper knowledge about how well students in different academic fields handle ICT is important to address their needs in becoming proficient users (European Commission, 2019).

The current study seeks to provide insights into prospective science teachers' and engineers' digital competences. The aim is to identify indicators among student's characteristics influencing the expression of digital competences and to furthermore identify patterns of competences that both together provide starting points for higher education institutions to support the development of digital competences among students.

### **Unpacking the Terminology**

Digital competence, digital literacy, computer and information literacy, internet skills, ICT literacy, or 21st century skills are typical keywords used to describe frameworks related to digitisation (Hatlevik & Christophersen, 2013; Ainley, Schulz, & Fraillon, 2016; Rohatgia, Scherer, & Hatlevik, 2016; van Deursen & van Diepen, 2013; Senkbeil & Ihme, 2017; Lee, Chen, Li, & Lin, 2018; Combes, 2009; van Laar, van Deursen, van Dijk, & Haan, 2017). When we look behind these concepts, we can, for example, identify emphasis on four areas: collecting and working with data, digital (knowledge) production, need of responsible and ethical standards, and communication (Siddiq et al., 2016).

The Educational Testing Service (ETS) Report of the International ICT Literacy Panel suggests that "ICT literacy is using digital technology, communications tools, and/or networks to access, manage, integrate, evaluate and create information in order to function in a knowledge society" (International ICT Literacy Panel, 2002, p. 16). Another definition by the IEA International Computer and Information Literacy Study (ICILS) defines ICT Literacy as an "individual's ability to use computers to investigate, create, and communicate in order to participate effectively at home, at school, in the workplace, and in society" (Fraillon, Schulz, & Ainley, 2013, p. 18). Finally, in the European framework for digital competences, a more detailed definition declares it as a "confident, critical, and creative use of ICT to achieve goals related to work, employability, learning, leisure, inclusion and/or participation in society" (Ferrari, 2013, p. 2). Common to these frameworks are that dealing with information, communication, and the need for developing competences to participate fully in an information society are seen as key aspects of understanding and using ICT. At the same time, all these definitions are rather general which creates problems when assessing digital competences.

The frameworks mentioned above suggest that an assessment of digital competences should, among others, measure to what extent students are able to actively use technology. In this context, an attempt was made to

systematize the existing frameworks and conditions. The Joint Research Centre Institute for Prospective Technological Studies (JRC-IPTS) initiated the project that, in the end, led to the European digital competence framework, called DigComp. The framework structure of the DigComp clusters digital competences within five domains (see Figure 1):

1. Information and data literacy,
2. Communication and collaboration,
3. Digital content creation,
4. Safety, and
5. Problem solving.

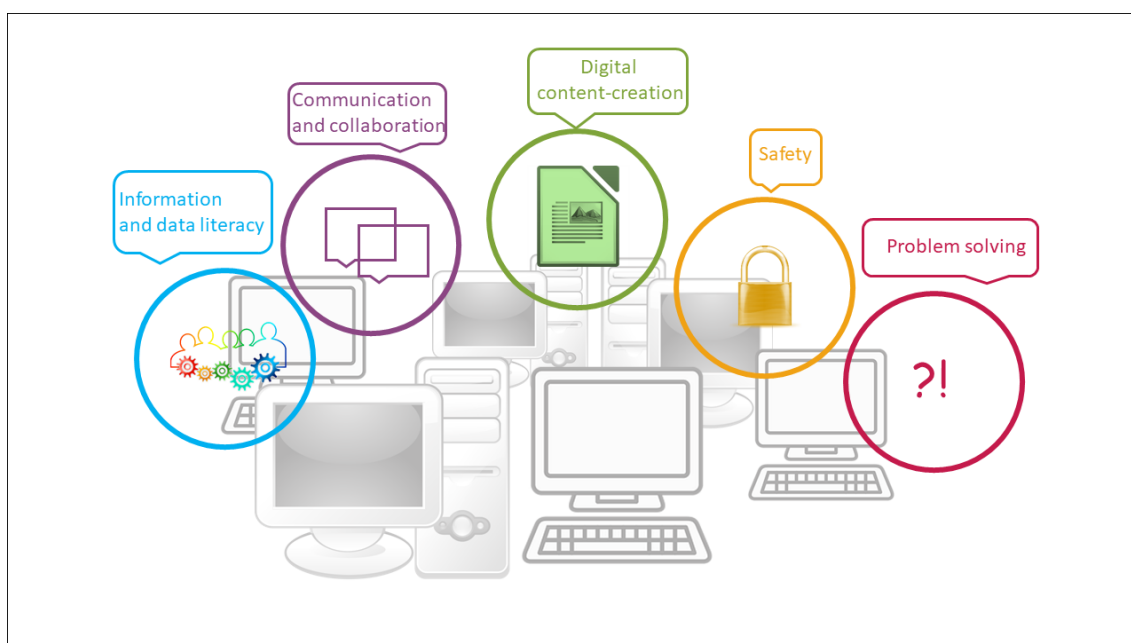


Figure 1. Overview of the Five Competences according to the European Framework of Digital Competences DigComp

The domain ‘Information and Data Literacy’ refers to the ability to identify, locate, retrieve, store, organize and analyze digital information. One aspect of this competence is to judge the relevance and purpose of information and data. Abilities related with the dimension ‘Communication and Collaboration’ cover the sharing of resources through online tools, connecting and collaborating through digital tools with other people. Communication and collaboration digital competences are the basis for interaction with and participation in communities and networks and for cross-cultural awareness. The dimension ‘Digital Content Creation’ is based on the qualification to create and edit new content (from word processing to image and video processing). These abilities focus on creative expression, media output and programming. Dealing with and applying intellectual property rights is also an important aspect, such as licensing. The dimension ‘Safety’ covers competences such as personal protection, general data protection, digital identity protection, security measures, for a safe and finally sustainable use of digital technologies. Lastly ‘Problem Solving’ refers to skills and knowledge of identifying digital needs and resources. Problem solving covers aspects of identifying the most appropriate digital tool for a task, the creative use of technologies and updating one’s own and other’s competences are

important facets in this dimension.

One national adaptation based on the DigComp framework is the German D21 Digital Index (Müller et al., 2018). The D21 Digital Index was introduced to picture the state of the nation's digital competences once a year since 2013, originally initiated by former German chancellor Gerhard Schröder in 2001 as (N)Onliner Atlas. The team behind the D21 Index is a consortium of about 100 representatives from politics, economy, and science, the results of the annual study have a great impact on society and policy making. Because the D21 Digital Index is based on the DigComp, it follows the same structure. The major differences between the DigComp and the D21 are that the latter has much shorter preambles introducing the different sets of questions and the items themselves are shorter.

### **Research Framing this Study**

Before we take a look at the bigger picture, we will briefly report recent survey results among university students in Germany which are relevant for this study: Firstly, all these studies conclude that students' digital competences need to be developed further (Leichner, Peter, Meyer, & Krampen, 2014; Rott, 2014). A more specific look takes Senkbeil, Ihme, and Schöber (2019). Using data derived from the German National Educational Panel Study (NEPS) the authors found that among almost 2000 students a high proportion of first-year students (20 %) and sixth-semester students (52 %) do not meet the foundational level of digital competences, showing differences in their ICT-related competencies depending on the area of study and gender. This finding is in accordance with international findings (Smith et al., 2013; Blignaut & Els, 2010).

### **Studies on Students Digital Competences**

It is without question that a major challenge for science and engineering education lies in the rapid and unpredictability of technological and social change. However, research and teaching development must focus on discovering identifiable knowledge assets and specific competences that could, with a certain degree of probability, empower both, engineering and teacher students to adaptively respond to possible future requirements (Gebhardt, Grimm, & Neugebauer, 2015). While there is a body of research on programme development for supporting digital competences in engineering higher education programmes (Gilliot, Garlatti, & Simon, 2010; Kamp, 2020), only few information on digital competences of engineering students are available. One study we found refers to information literacy among Malayan students. Here the researchers found that participants seriously lacked the knowledge and skills to "evaluate internet information, to identify the most efficient search strategy, to use scholarly resources, and to use information ethically." In a survey among 78 business engineering students Fleaca and Stanciu (2019) asked students to estimate their digital competences.

Partially drawing on the DigComp, the results show that students are confident in their 'information and data processing skills' as well as 'communication skills' but show a lack of ability to distinguish reliable online sources from unreliable information. Scores were low for the tasks 'constructing different e-profiles' and for

‘selecting information to share according to own needs or targets. Furthermore, the survey found that most of the prospective engineers are not confident about their capacities to explore original formats and new ways for content creation and to exploit technological potentials to represent and solve problems. We found another study conducting a comparison of prospective teachers’ and engineering students’ digital competences: Šerbec et al. (2016) examined the digital competences of university students from Macedonia and Slovenia using a version of the DigComp. They found for both countries that the biggest gap between current and desired level of digital competences lied in the domains of problem solving and safety. Furthermore, they found that in all five competence areas the engineering students scored higher than the teacher students, but no further information on the majors of the study programs were given.

As well as in engineering, a high level of digital competence is needed in the teaching professions. First, it is a general agreement that within teacher education ICT has added complexities (Koumachi, 2019; Instefjord & Munthe, 2017; Pettersson, 2018; Krumsvik, 2014). In this context Krumsvik (2014) contends that professional digital competence is more complex in the teaching profession as opposed to other occupations or amongst average citizens, as there are two dimensions. The first relates to their ability to use technology in a seamless way to encourage students to mirror the personal use. The second is pedagogical in its focus as teachers must also simultaneously and continually “make pedagogic-didactic judgments which focus on how ICT can expand the learning possibilities for pupils in subjects” (Krumsvik, 2008, p. 283). Lund and Erikson (2016) also identify this ‘double challenge’ for teachers, ranging from ‘substitutional’ uses to ‘redefinition’ where the use of the technology provides opportunities for new tasks made possible using technology. While this view has gained increasing popularity amongst educators, Hamilton, Rosenberg and Akcaoglu (2016) state that such a view 1) downplays important contextual factors such as resources and infrastructure and school leadership, 2) imposes a ridged hierarchical structure to teachers’ technology use and 3) focuses on changing the instructional activity rather than the learning process.

Teacher educators and educational researchers report about many teachers having positive attitudes towards digital technology, but digital competence among prospective and active teachers still needs improvement (Koc, 2013; Gudmundsdottir & Hatlevik, 2018; Bergeson & Beschoner, 2020). According to Dittmar and Eils (2019) German teachers are hesitating to integrate digital tools such as internet forums in their teaching (Dittmar & Eilks, 2019). But the desire of many teachers to receive more training in using ICT for education shows their desire to meet the challenges and chances of digitization in their classrooms (Paje, Rogaya, & Dantic, 2021). Anyhow, the landscape is complex since a vast body of research shows a lack of homogeneity in relation to ICT skills as well as knowledge amongst the younger generations and in relation to pre-service teachers (Chen, Lim, & Tan, 2010; So, Choi, Lim, & Xiong, 2012). Gill, Dalgarno and Carlson (2015) conclude that the use of technology in the students’ social life does not necessarily translate to a competent use in learning and teaching. Furthermore, Cebi and Reisoglu (2020) found in a recent study using the DigComp framework that pre-service teachers score high in the areas of information and data literacy, communication and collaboration, and safety but scores for digital content creation and problem-solving were low. Napal Fraile, Peñalva-Vélez and Mendióroz Lacambra (2018), also using the DigComp, make a similar finding with students scoring lowest in content creation and problem solving and high in information literacy.

## **Digital Divide**

The term digital divide is linked to the concept of social inequalities (Ragnedda & Muschert, 2016). The core findings are, that differences in access to and use of ICT depend on population segment characteristics and country (DiMaggio et al., 2001; Castells, 2002; Witte & Mannon, 2010). In relation to digital competences, researchers monitor socio-economic status, ethnicity, gender, access to the Internet and technology (Rowell, Morrell, & Alvermann, 2017), as influential to an individual's development of digital competences. Most studies, for example, reveal a gender gap with respect to digital competences in primary and secondary schools (Cooper, 2006; European Parliament, 2018), and show a correlation between socioeconomic status (SES) and ICT literacy. For example, Siddiq and Scherer (2019) show a correlation between SES and ICT literacy with  $r = 0.21$ . Research also points out that the patterns of digital divide transgress into higher education (Murray & Pérez, 2014; Schulze Heuling & Wild, 2021). Therefore, we will pay attention towards the question if the competence gap among students related to SES and gender reproduces in this study. If so, this would require attention from teacher educators and higher education institutions (Goldhammer, Gniewosz, & Zylka, 2016; Kaarakainen, Kivinen, & Kaarakainen, 2017). Therefore, we combine in our study the analysis of digital competence and the individual use of digital applications and services with socio-demographic and socioeconomic factors.

## **Methodology**

In a cross-sectional design we collected data from 180 students at a University and a University of Applied Sciences in Germany by paper and pen (Schulze Heuling & Wild, 2019). Participation was voluntary and no incentives were given. Privacy policy was adhered to. One reason we chose this survey to be paper and pen is that the questionnaire was used in a collaborative project between several universities distributing it within different settings among several cohorts of students. The other reason is that paper and pen surveys are still very common in Germany. Furthermore, there is evidence that paper and pen surveys among students have a lower sample bias than digital surveys (Weber & Brake, 2005, p. 78).

## **Instrument**

In this study we used the German D21-index survey instrument as reported by Müller et al. (2018) in a slightly modified version. We used self-reports, allowing the respondents to choose a single option from each item in the questionnaire, if the item was relevant. All items are listed in Table 2. The decision to measure the items based on self-reports was based on the arguments put forth by Lucas and Baird (2006, p. 41) that "although errors surely do occur, they often do not severely limit the validity of the measures".

We assessed the instrument quality based on item response theory (IRT) according to Birnbaum (1968). IRT is often used in education when measuring competence or knowledge, for example in large-scale-assessments such as PISA (Cresswell, Schwantner, & Waters, 2015). Since several different statistical models are available to assess item and test taker characteristics (Hartig & Goldhammer, 2010) it is of importance to test which of the

models yields the best fit to the data. The most prominent IRT model is the Rasch model. Less prominent is the Birnbaum model. We assessed the instrument quality comparing both model fits. A summary of the results is given below while a full report of the quality analysis of the testing instrument can be found in Wild and Schulze Heuling (2021).

In our sample the five dimensions with a total of 24 items show an acceptable measurement quality and are empirically separable. Every scale was introduced with the question “What can you do, recognize or how is your behavior?” Reliability analysis revealed the following: (1) Information and data literacy. EAP/PV-Reliability = .66; 5 Items; item example: “Data transmission between devices”, (2) Communication and Collaboration. EAP/PV-Reliability = .64; 4 items; item example: “Recognizing fake news”, (3) Digital Content creation. EAP/PV-Reliability = .69; 5 items; item example: “Design web applications”, (4) Safety. EAP/PV-Reliability = .56; 5 items; item example: “Regular updates of antivirus software”, and (5) Problem Solving. EAP/PV-Reliability = .74; 5 items; item example: “Learning to use new program versions”. A confirmatory factor analysis was applied to analyze the instrument by Weighted Least Squares Mean Variance (WLSMV), showing a good fit ( $\chi^2 = 987.003$ ,  $df = 242$ ,  $p < .001$ ;  $CFI = .971$ ;  $TLI = .967$ ;  $RMSEA = .052$ ) according to Xia and Yang (2018) who consider  $RMSEA \leq .05$  and  $CFI, TLI \geq .95$  to be acceptable values. The dimensions ‘Information and data literacy’, ‘Communication and collaboration’ and ‘Problem solving’ have loadings above  $\lambda > .50$ . The loadings for the two other dimensions ‘Digital content creation’ and ‘Safety’ are less satisfying, because four items range between  $\lambda = .23$  and  $\lambda = .31$ . For further explorative analyses, the regularly used digital services and applications were assessed, also using a slightly modified version of the instrument presented by Müller et. al. (2018, p. 16). This list of items was introduced with the question: “What activities do you carry out regularly, meaning once or several times a week?” . The items are dichotomous meaning participants could agree with these items or refuse. Table 1 provides a full overview of the items assessed.

Table 1. Items and Dimension of Digital Competences in Translation and in their Original Language. Anchoring: “Think about your digital skills. What can you do, recognize and what is your behavior?”

<b>Item in English</b>	<b>Item in German (original)</b>
<i>Information and data literacy</i>	<i>Informationsverarbeitung</i>
Internet research	Internetrecherchen
Data transmission between devices	Datenübertragung zwischen Geräten
Use of multiple sources	Nutzung mehrerer Quellen
Recognition of advertisements	Erkennen von Werbeanzeigen
Level of attention for search results, beyond the first page	Beachtung von Suchtreffern über die erste Seite hinaus
<i>Communication and collaboration</i>	<i>Kommunikation</i>
Online bank transfer	Online-Überweisung
Recognizing fake news	Erkennen von Fake News
Posting information on social networks	Inhalte in soziale Netzwerke einstellen
Handling hostility on social networks	Umgang mit Anfeindungen über soziale Netzwerke
<i>Digital content creation</i>	<i>Erstellen von Inhalten</i>



<b>Item in English</b>	<b>Item in German (original)</b>
Create articles (text programs)	Texte erstellen (Textprogramme)
Create calculations (tabulation program)	Berechnungen erstellen (Tabellenprogramme)
Create a presentation	Präsentationserstellung
Design web applications	Webanwendungen gestalten
Programming	Programmieren
<i>Safety</i>	<i>Schutz und Sicherheit</i>
Awareness of services / app sharing	Bewusstsein, dass Dienste / Apps Daten weitergeben
Transferring of data	
Posting few personal data online	Wenige persönliche Daten ins Netz stellen
Regular updates of antivirus software	Regelmäßiges Update der Antivirensoftware
Changing password regularly	Regelmäßiger Passwortwechsel
Awareness of the server origin (country)	Bewusstsein der Serverherkunft (Land)
<i>Problem solving</i>	<i>Problemlösung</i>
Installation of devices	Installation von Geräten
Establishment of a (home)network	Einrichtung (Heim-) Netzwerk
Helping other persons with problems on the Internet and PC	Anderen bei Internet- und PC-Problemen helfen
Connecting hardware to a device	Hardware anschließen
Learning to use new program versions	Mich in neue Programmversionen einarbeiten.

Table 2. Items of Regular Activities in Translation and in their Original Language. Anchoring: “What activities do you regularly, like once or several times a week?”

<b>Item in English</b>	<b>Item in German (original)</b>
Looking for content and information in search engines	in Suchmaschinen nach Inhalten und Informationen suchen
Using of office tools	Office-Programme nutzen (z. B. Textverarbeitung, Tabellenkalkulation, Präsentationen)
Watching online videos	Online Videos ansehen (z. B. YouTube)
Using map services / navigation systems	Kartendienste / Navigationssysteme nutzen (z. B. Google Maps)
Using instant messaging service	Instant-Messaging-Dienste nutzen (z. B. WhatsApp, Threema, Telegram)
Using cloud-services	Nutzung von Cloud-Services (z. B. Dropbox, Google Drive, Amazon Drive)
Using on-demand services or streaming	On-Demand-Dienste oder Streaming nutzen (z. B. Spotify, Netflix, Amazon Prime)
Using smart home applications	Smart-Home-Anwendungen nutzen (z. B. „intelligente“ Heizungssteuerung per App)

## Data Analysis

To achieve the main objective of the study we follow a three-step analysis. First, we looked at differences between the mean values occurring among the five digital competence areas using *t*-Tests, followed by a Latent Profile and Correspondence analysis. We conducted a latent profile analysis (LPA) with the aim to cluster students in groups of consistent homogeneity related only to the level of digital competence (Oberski, 2016). We used five different models to balance our decision of the LPA result: For analysing the number of profiles we used the decision Aikake information criterion (AIC) and the Bayesian information criterion (BIC). Another quality measure is the entropy criterion with a maximum value of 1 (Celeux & Soromenho, 1996). We also calculated the diagonal of the average latent profile probabilities for most likely profile membership aiming for values above 0.80 for each latent profile (Jung & Wickrama, 2008).

Finally, we conducted a bootstrap likelihood ratio test (BLRT) which provides *p* values assessing whether adding a profile leads to a statistically significant improvement in model fit or not. These likelihood-based tests compare the fit between two neighbouring profile models (e.g., a two-profile versus a three-profile model). No significant *p* value for a *k*-profile solution thus supports the *k* - 1 profile solution (Nylund, Asparouhov, & Muthén, 2007).

In the third and final step of this study we applied a correspondence analysis (Benzecri, 1992) to gain more information on the characteristics of each profile from the precedent LPA. This method is particularly suited to explore relationships among qualitative variables. One goal is to gain as much variance as possible in the model with the least number of dimensions of the inertia at the same time. The results are interpreted mostly based on a bi-plot. The bi-plot provides a visual display of each of the values and provides a global view of the trends and correlations within the data. Shorter distances between the variables indicate a higher correspondence. Additionally, variables located in the same quadrant are connected positively.

In our data missing values are low and vary between 0 % and 5 %. An imputation by an Expectation Maximization Algorithm was done (Peugh & Enders, 2004). For analysing we used SPSS (Version 26) and Statistic Software R with the packages “tidyLPA” and “tidyverse” for latent profile analysis and for multiple correspondence analysis the packages “FactoMineR”, “factoextra” and “gplots”.

## Results

### Sample Description

In our sample 58 % of the participants were prospective science teachers from Europa-Universität Flensburg with majors in either physics or chemistry; 42 % were enrolled at Flensburg University of Applied Sciences in engineering (Bachelor: Marine Engineering or Energy Engineering) (see Table 1). The average age of the participants in the sample was  $M = 21.96$  years ( $SD = 1.93$ ). 40 % of the engineering students and 45 % of the teacher students report to have at least one parent with academic background – a not significant difference ( $\chi^2(1, 180) = .44, p = .51, \Phi = .05$ ). Social background was measured by a subjective self-report on the question “What

social class did you belong to when you were 15 years old?” and had to be ranked on a scale between 1 (= lowest) and 10 (= highest). Self-estimation of SES reached a mean of  $M = 5.89$  ( $SD = 1.47$ ). Students at Flensburg University of Applied Sciences ( $M = 5.97$ ;  $SD = 1.49$ ) ranked themselves higher than students from Europa-Universität Flensburg ( $M = 5.83$ ;  $SD = 1.44$ ). Again, there was not a significant difference ( $t(178) = .66$ ,  $p = .51$ , *Hedges' g* = .10). On average the students were in their second academic year ( $M = 1.72$ ;  $SD = .81$ ). Nearly 91 % of the students had a university entrance qualification (Abitur; 94 % of the teacher students and 85% of the engineering students,  $\chi^2(1, 180) = 4.10$ ,  $p < .05$ ,  $\Phi = .15$ ). A minority entered the study program via a side entry procedure for which a minimum of five years of work experience and a passed entrance exam are compulsory. 38 % of the students completed a vocational apprenticeship prior to their studies. The analyses showed that prospective teachers ( $M = 22.55$ ;  $SD = 1.69$ ) taking part in our study were significantly older than the prospective engineers ( $M = 21.12$ ;  $SD = 1.95$ ) with a medium effect size,  $t(178) = 5.26$ ,  $p < .001$ , *Hedges' g* = .75. This corresponds with a large effect size for prospective teachers ( $M = 1.99$ ;  $SD = .86$ ) being in a higher academic year than prospective engineers ( $M = 1.37$ ;  $SD = .52$ ),  $t(178) = 5.53$ ,  $p < .001$ , *Hedges' g* = .84.

Table 3. Student Characteristics and Mean Values for n = 180 Participating Students

Item	Proportion / Mean ( <i>M</i> ) with Standard deviation ( <i>SD</i> )
Age	$M = 21.96$ $(SD = 1.93)$
Social Background*	$M = 5.89$ $(SD = 1.46)$
Academic Year	$M = 1.73$ $(SD = .80)$
Academic major	
Teacher	58 %
Engineer	42 %
Vocational apprenticeship	
Yes	38 %
No	62 %
University entrance qualification	
Yes	91 %
No	9 %
Parents with an academic background	
Yes	41 %
No	59 %
Sex	
Male	58 %
Female	41 %
Could not assigned to a male or female	1 %

\* self-estimation, ranging from 1 (= lowest) to 10 (= highest)

**Descriptive Analysis of Digital Competences**

Table 4 and Figure 3 show the *t*-Test results comparing students’ digital competences according to their study program. At baseline, no statistically significant differences between the groups were observed. However, the area of study has a small effect on the competence domain digital content creation ( $t(178) = 1.63, p = .18, Hedges' g = .22$ ). Here prospective engineers scored slightly higher compared to future teachers.

Table 4. Comparing Digital Competences between Academic Field Teachers and Engineers by *t*-Tests

	Teachers (n = 105)		Engineers (n = 75)		<i>p</i>	Hedges' <i>g</i>
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>		
Information and data literacy	-.25	.52	-.20	.47	.55	.10
Communication and collaboration	.01	.75	.03	.69	.91	.03
Digital content creation	.16	1.18	.42	1.31	.18	.22
Safety	.52	1.10	.55	1.16	.90	.03
Problem solving	.43	.78	.43	.73	.97	<.01

*Note.* Table show standardized values of the estimated thetas by the Birnbaum Model

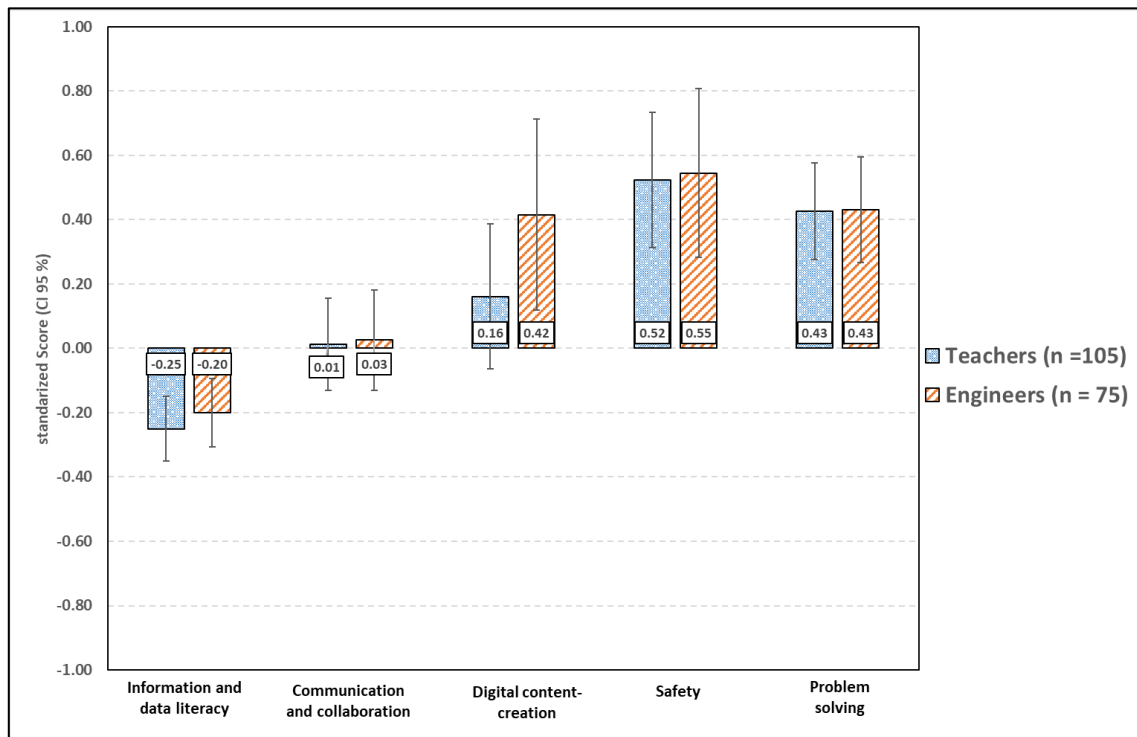


Figure 2. Comparing Digital Competences between Academic Field Teachers and Engineers

**Exploring Different Profiles of Digital Competences**

A latent profile analysis was used to identify typical profiles of digital competences hidden in the data. We

compared the statistical solutions for profile numbers from one to five. The best statistical result achieved the four-profile solution. Table 5 shows the results of the analysis. AIC continuously decreases from the solution with one profile to the solution with five profiles. However, the Bayesian information criterion analysis shows a preference for the four-profile solution ( $BIC = 1760.49$ ).

Entropy analysis also suggests a solution with four profiles, because this solution has the highest entropy value (Entropy = .99). The diagonal of the average latent profile probabilities for most likely class membership is ambivalent. Here, the solution with three as well as with four profiles has the same diagonal of the average latent profile probabilities for most likely profile membership with highest minimum (95 %) and highest maximum (100 %). We also considered a bootstrap likelihood ratio test to determine the profile number solution with highest p-values for the 4- and 5-profile solution. Finally, taking into consideration also the overall profile occupancy we concluded the best solution for the numbers of profiles to be four.

Table 5. Fit Statistics of Latent Profile Analysis (n = 180)

Profile	AIC	BIC	Entropy	minimum	maximum	BLRT <i>p</i>
				average latent class probabilities for most likely latent class membership	average latent class probabilities for most likely latent class membership	
1	2220.91	2252.84	-	-	-	-
2	1937.63	1988.71	.93	.94	.99	.010
3	1762.22	1832.46	.98	.95	1	.010
4	1671.09	1760.49	.99	.95	1	.010
5	1666.03	1774.59	.89	.75	1	.040

*Note:* Akaike information criterion (AIC), Bayesian information criterion (BIC) and Bootstrap likelihood ratio test (BLRT)

Figure 3 shows the four profiles of the analysis for digital competences. 27% of the students belong to the profile with “HIGH digital competences”. In all five competence dimensions this profile scored highest, especially in the dimension digital content creation. The second profile with “rather HIGH digital competence” contains 44 % of our sample and is, at the same time, the profile with the highest occupation number. In the dimensions ‘information and data literacy’ as well as ‘communication and collaboration’ the profile of rather HIGH digital competences is comparable to the profile HIGH digital competence. But the scores for ‘digital content creation’ as well as ‘safety and problem solving’ are closer to the profile showing “rather LOW digital competence”.

About 21 % of the participating students belong to the latter profile. The Profile “LOW digital competences” scores lowest in all five dimensions. A total of 8 % of the students were assigned to this profile. The latent profile analysis (LPA) tells us, how many characteristically homogeneous groups can be found among a sample.

But LPA does not tell us the characteristics of the students belonging to each profile. To answer this question, we turn towards correspondence analysis.

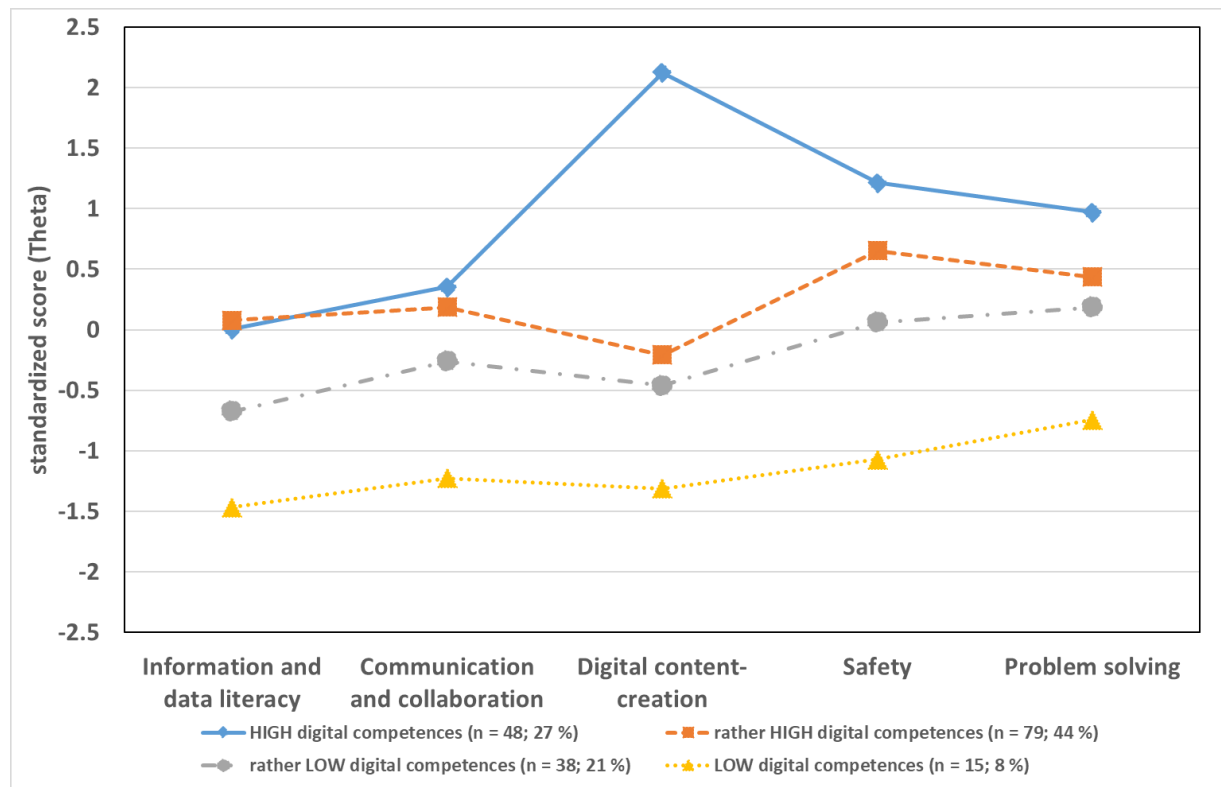


Figure 3. Four Profiles of Digital Competence according to the Latent Profile Analysis

### Differences in the Competence Profiles, Digital Activities and Demographic Data

For further analyzing the four digital competence profiles we consider the information students gave us on their digital activities and demographic data. To assess this complex task in a multivariate way we use multiple correspondence analysis. We see in the bi-plot (Figure 4) that the demographic characteristics of students span up the y-axis of the bi-plot while the level of digital competence distributes among the x-axis. Total inertia is 1.23, which is good. Furthermore, with this solution we can explain nearly 38 % of the variance in the two dimensions, a satisfactory result.

The central task to correspondence analysis is, as we mentioned earlier, to interpret the bi-plot (see Figure 4). In our study the bi-plot discloses the key student characteristics corresponding with each of the four competence profiles. One central finding can be withdrawn from a look at the x-axis. Here we see that the analyzed profiles with higher digital competences are in close vicinity to many digital services and applications that are used on a regular basis (several times a week). In contrast to this, the profile “LOW digital competences” finds itself on the right side of the plot and does not correlate at all with the frequent use of any of the digital services or applications we surveyed.

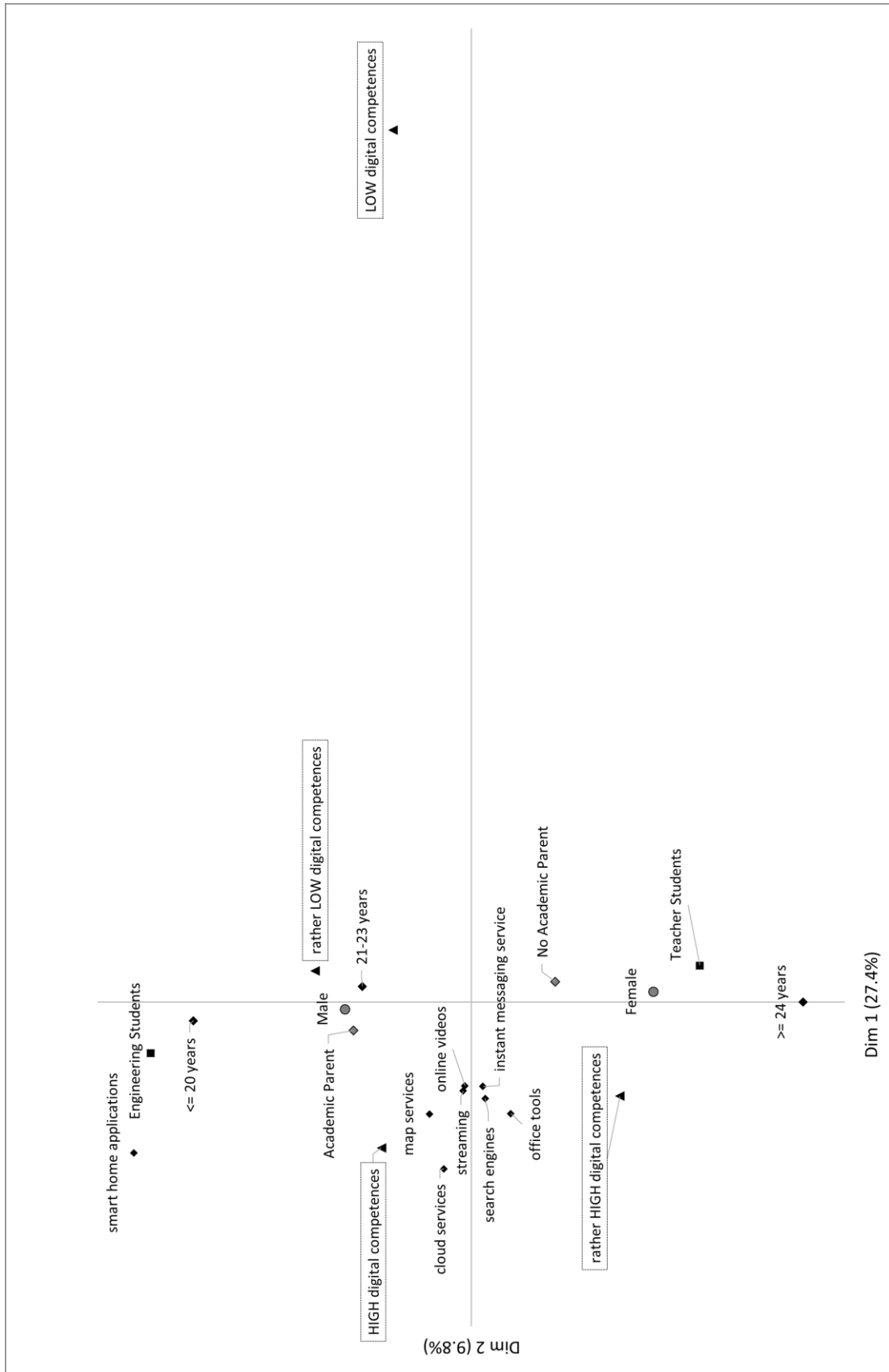


Figure 4. Visualization of Correlation between Level of Digital Competence, Digital Activity and Demographic Data according to the Correspondence Analysis (n = 180) [among the x-axis distribute the levels of digital competence while the y-axis is largely determined by the age of the participants]

A more detailed analysis shows that the variables 'Smart Home Applications', 'Engineering students' and '20 years or younger' form a small cluster at the top of the y-axis in the second quadrant. A little lower we find two clusters, one in the first and the other in the second quadrant of the bi-plot. The cluster in the first quadrant aggregates the profile with 'rather low digital competences' (21 % of the students) and the age interval '21 to 23 years', suggesting a correspondence between those two variables. In contrast to this the cluster in the second quadrant discloses more information on variables being characteristic for students with high digital competences (27 % of the students). Here the demographic variables 'male' and 'parent with academic degree' and the applications 'map services', 'cloud services', 'Streaming', and 'watching online videos' group around high digital competences suggesting a linkage between frequent digital activity, high socio-economic background and sex. The predominantly frequent use of cloud services by 27 % of the inquired students is in correspondence with a recent study among prospective teachers conducted by McGarr and McDonagh (2020) in which 21 % of the participants approved frequent cloud service usage.

Another cluster has formed in the third quadrant where different variables are situated around the competence profile 'rather high digital competences' (44 % of the students). Here the applications 'instant messaging service', 'search engines', and 'office tools' are predominantly characteristic for students assigned to this profile. Finally, in the fourth quadrant, we find a cluster of three demographic variables: (1) 'parents without academic background', (2) 'female', and (3) 'teacher student', suggesting a correspondence between these traits. While a correspondence between male students of high economic background and the expression of most elaborated digital skills was found, the female students cannot be unidirectional assigned to one characteristic competence profile. However, more characteristics for the female students are to become a teacher and not having academic parents. Noteworthy is the positioning of the lowest competence profile (8 % of the students). This resides in the first quadrant far away from any of the variables we assessed. This means that none of the assessed student characteristics is crucial for the expression of low digital competences.

## **Discussion and Outlook**

In the presented study we analyzed the digital competences of prospective engineers and science teachers using the D21 digital index, the German version of the European reference framework for assessing digital competences, DigComp. Comparison of the mean values showed no significant differences in digital competences between the prospective engineers and the prospective science teachers. This is in accordance with the research from Senkbeil et al. (2017). We stated earlier in this report. However, a latent profile and correspondence analysis revealed other relations between the variables. To begin with, the latent profile analysis showed that that 71 % of the students we assessed have high or rather high digital competences and that 8 % of the students score very low in all five dimensions. This is better than the studies we cited above in which between 20 % and 50 % of the students lacked fundamental ICT knowledge. The relatively good overall score students yield in this study might root in the fact that we surveyed STEM-students only – a group which typically scores above average in surveys within the field of digital competences.



The correspondence analysis showed that prospective engineers tend towards more complex digital activities. But the bi-plot revealed no explicit information on the digital competences of those students. Furthermore, no explicit information on prospective teachers' digital competences could be withdrawn from the bi-plot. What we do see is that prospective teachers are predominantly associated with the characteristics female and lower SES. The data furthermore shows a positive correspondence between high SES and the expression of high digital competences according to the cluster formed in the second quadrant. In close vicinity to the latter characteristics is also the variable "male gender". In the overall view of the bi-plot, we interpret that our data reproduces the patterns of the gender-related digital divide. We can also confirm the other proposition of the digital divide, the correlation between high SES and expression of high digital competences. We furthermore find in our data that elaborated digital competences are in accordance to being digitally active – or vice versa. This is important information because the more active a person is, the more she or he might be participating in the digital world and implicitly training the digital competences.

From this we carefully suggest that another, not surveyed factor, might be significantly influential on the expression of digital competence: the impact of implicit learning. The relationship between a high digital activity and high digital competence points towards what we know from the literature: that common computer tasks such as carrying out web searches or doing simple programming tasks have a high impact on implicitly developing digital competences (Mancy, 2007; Greene, Yu, & Copeland, 2014). But as stated earlier, we have to take into consideration that the use of technology in the students' social life does not necessarily translate to a competent use in learning and working. We can carefully conclude from our data that teacher and engineering education has had limited success in integrating digital competency as an integral part of the education programs. Since gender and SES are an influencing factor on the formation of digital competences educational institutions and educators should take this into consideration in future planning.

However, what our study did not reveal are factors corresponding with the expression of low digital competences. This would be necessary to effectively promote the acquisition of general and profession related digital competences. This is even more important for the 8% of the students with less developed digital competences. It is them who need particularly be prepared for the challenges of a digitized world. Not having found any indicators constituting this group leaves us with a challenge for future studies.

Strengthening engineering students' digital competences is crucial because they need knowledge of virtualized or remotely controllable interfaces and process systems. Digital media and artifacts in engineering professions typically present a strong fusion of methodological and content-related knowledge, such as SPS programming. To face such challenges training versatile digital skills and competences are indispensable. And science teachers have to provide both, up-to-date teaching methodologies and supporting the formation of digital skills in their students. Our data provides universities and colleges with information on specific groups of students. With this in mind they can now develop group-specific communication and action to foster prospective teachers' and engineers' digital competences.

Lastly, both, engineers and teachers, are placed at professionally vulnerable positions: their digital competency

encompasses a broader understanding of ethical and legal aspects of digital technologies in industry and education that are having an ever more increasing impact on professional, but also on personal lives (Richert, Shehadeh, Willicks, & Jeschke, 2016; European Commission, 2017). For example, issues associated with informational security, data safety, handling and privacy are some of the important issues encompassed by digital competence. This shows that it is even the more crucial to raise the level of digital competence. What this study does not answer is in how far the higher education teaching personnel needs a rise in their digital competences, too.

Despite the interesting results, our study has certain limitations. We used self-reports, which is a common method that comes along with specific advantages and disadvantages (Döring & Börtz, 2016; McDonald, 2008). A major disadvantage is that this method anticipates socially desired responses and the bias induced by the participants' self-perceptions. Furthermore, as we stated in the beginning, we know there is a personal-professional gap between individually perceived competence and measured levels of digital technology used in education. However, according to Klieme, Artelt and Stanat (2002) it is possible to obtain a valid picture of central aspects of "competencies" based on self-reports.

Our study has shown that it is always worth to take a deeper look into data and to go beyond the comparison of mean values. Specifically, the strength of this study is that it does not only use demographic variables to study the reproduction of the digital divide or to propose differences between two different cultures of studies. Instead, we applied an explorative analysis and were able to uncover relations between digital competences and student characteristics which were not obvious before.

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